DIURNAL MARINE DISTRIBUTIONS OF RADIO-TAGGED CASSIN'S AUKLETS AND RHINOCEROS AUKLETS BREEDING AT TRIANGLE ISLAND, BRITISH COLUMBIA

Laura McFarlane Tranquilla[1], John L. Ryder[1], W. Sean Boyd[2], Steven G. Shisko[2], Krista Amey[2], Douglas F. Bertram[1,3] and J. Mark Hipfner[1,2]

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ABSTRACT

We completed a three-year (1999-2001) radio-telemetry study to determine the diurnal marine distributions of Cassin's Auklets (*Ptychoramphus aleuticus*), and report the first such data (2002) for Rhinoceros Auklets (*Cerorhinca monocerata*), breeding at Triangle Island, British Columbia.

We attached radio-transmitters to 38 adult Cassin's Auklets during the chick-rearing period from 14-23 May 2001, and conducted aerial surveys to locate the radio-tagged birds from 5-7 June 2001. We detected 76% of the radio-tagged CAAU at sea on at least one occasion, concentrated in an area ca. 60 km northwest of Triangle Island. Males were significantly closer to the colony than females, and birds from different areas of the colony had similar marine distributions. This pattern of marine distribution was significantly different to that found in 1999 and 2000, when Cassin's Auklets were concentrated 30-60 km southwest of Triangle Island.

We also attached radio-transmitters to 40 Rhinoceros Auklets during the chick-rearing period from 1-8 June 2002, and conducted telemetry aerial surveys to locate the birds [illegible] 18 July 2002. We detected 43% of radio-tagged RHAU at sea on at least one occasio[illegible], [illegible] which were located at sea on 17-18 July 2002, ca. 60 km northwest of Triangle Island.

The distance to foraging locations is critical for the interpretation of energy expenditure during the reproductive cycle of Cassin's and Rhinoceros Auklets. In addition, our findings will contribute to marine conservation efforts, by improving parameters for boundary definition around the proposed Scott Island Marine Wildlife Area. This can also assist in the mitigation of threats posed by exploration and development of non-renewable resources, the impacts of fisheries, and environmental disasters such as oil spills.

RÉSUMÉ

Nous avons terminé une étude radiotélémétrique triennale (1999-2001) qui visait à déterminer les répartitions marines diurnes du Starique de Cassin (*Ptychoramphus aleuticus*) et rapportons les premières données (2002) de ce type pour le Macareux rhinocéros (*Cerorhinca monocerata*) pour la région de l'île Triangle (Colombie-Britannique), où nichent ces espèces. Nous avons muni de radioémetteurs 38 Stariques de Cassin adultes durant la période d'élevage des petits du 14 au 23 mai 2001, puis effectué des relevés aériens pour localiser ces oiseaux du 5 au 7 juin 2001. À au moins une occasion, nous avons repéré en mer 76 % des Stariques de Cassin porteurs de radioémetteurs, concentrés dans une zone située à environ 60 km au nord-ouest de l'île Triangle. Les mâles étaient significativement plus près de la colonie que les femelles, et les oiseaux provenant des différents secteurs de la colonie montraient des répartitions marines similaires. Ce profil de répartition marine était significativement différent de celui observé en 1999 et en 2000, années où les Stariques de Cassin étaient concentrés à 30-60 km au sud-ouest de l'île Triangle.

Nous avons aussi muni de radioémetteurs 40 Macareux rhinocéros durant la période d'élevage des petits du 1er au 8 juin 2002, puis effectué des relevés télémétriques aériens pour localiser ces oiseaux du 15 au 18 juillet 2002. À au moins une occasion, nous avons repéré en mer 43 % des Macareux rhinocéros porteurs de radioémetteurs, la plupart se trouvant en mer les 17 et 18 juillet, à environ 60 km au nord-ouest de l'île Triangle.

La distance des lieux d'alimentation est un paramètre critique pour l'analyse des dépenses énergétiques durant le cycle reproducteur chez le Starique de Cassin et le Macareux rhinocéros. Nos résultats contribueront aux efforts de conservation du milieu marin en ceci qu'ils précisent les paramètres nécessaires à la délimitation de l'éventuelle réserve marine d'espèces sauvages des îles Scott. Ils pourront aussi contribuer à l'atténuation des menaces que présentent la prospection et l'exploitation des ressources non renouvelables, des impacts des pêches et des catastrophes environnementales comme les déversements d'hydrocarbures.

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INTRODUCTION

Information on marine distributions of known breeders from seabird colonies has been a serious gap in conservation planning. To help conserve seabirds in British Columbia, information is needed on their at-sea foraging distributions during the breeding season (Gaston 1996, Burger *et al.* 1997, Drever 1999). The Scott Island Group, home to 13 seabird species, is the most important site for breeding seabirds in British Columbia, and was designated as an Important Bird Area (IBA) in 2001. Surveys conducted in 1989 estimated that the islands support 2.2 million breeding seabirds, including ca. one million, or 55% of the world's population, of Cassin's Auklets (*Ptychoramphus aleuticus*), and ca. 80 000, or 7% of the world's population, of Rhinoceros Auklets (*Cerorhinca monocerata*) (Rodway *et al.* 1990, 1992; Canadian IBA database 1998).

Marine Wildlife Areas (MWA) have been proposed as a conservation tool to protect marine species where they concentrate in high numbers (Petrachenko and Thompson 1998, Dunn and Morgan 1999). Because of the significance of the Scott Islands to seabird populations, Environment Canada's Canadian Wildlife Service is leading an initiative to establish a MWA near the Scott Islands. The proposed Scott Islands MWA focuses on sustainability of the area to support migratory seabird populations, and where possible, minimize human impacts. This proposed MWA initiative reflects Environment Canada's responsibility to protect Canada's wildlife and its habitat, under the Migratory Birds Convention, the Canada Wildlife Act, the Species at Risk Act, and other legislation and cooperative initiatives (CWS *unpubl. report*).

This report focuses on the concluding year of a three-year investigation of foraging distributions of Triangle Island's Cassin's Auklets (see Boyd *et al.* 2000, Ryder *et al.* 2001), to compare this distribution to the two previous study years which had shown a consistent pattern. This report also provides the first data on foraging distributions of Triangle Island's Rhinoceros Auklets.

In an area with multi-species colonies, the marine distribution of Cassin's Auklets (which provisions chicks primarily with zooplankton; Vermeer 1981), is of limited utility when used as a single parameter contributing to the delineation of MWA boundaries. Expanding the study to include marine distributions of Rhinoceros Auklets, a piscivorous species (Wilson and Manuwal 1986) also breeding at Triangle Island, was recognized as an important consideration. Thus, our primary objectives were to describe the marine distributions of Triangle Island's (1) planktivorous Cassin's Auklets, and (2) piscivorous Rhinoceros Auklets, in order that these distributions might be used to help delineate MWA boundaries around the Scott Island group.

It is known that seabirds travel to marine areas distant from their breeding colony specifically to forage (Gaston and Nettleship 1981,Obst *et al.* 1995, Pennycuick *et al.* 1984, Russell *et al.* 1999, Wanless *et al.* 1990). Thus, although we could not confirm whether the seabirds detected at sea were foraging for themselves or for their chicks (Gaston and Nettleship 1981, Davoren and Burger 1999), in this study, we made the assumption that birds detected at sea were foraging, and we used the terms "marine distribution" and "foraging distribution" interchangeably.

METHODS

Study area

Triangle Island (50° 52'N; 129° 05'W) is off the northwest tip of Vancouver Island, 46 km from Cape Scott. It is the outermost island in the Scott Islands chain (Fig. 1A) and is near the both the 1000 m and 200 m isobaths (Fig. 1B), where oceanic fronts and their subsequent influence on zooplankton populations can attract dense concentrations of foraging seabirds (Hay 1992, Logerwell *et al.* 1996, Russell *et al.* 1999, Hunt 1997).

Adult capture and transmitter attachment

Cassin's Auklets

From 14-23 May 2001, we radio-tagged 38 adult Cassin's Auklets at three locations in West Bay, Triangle Island (Fig. 2). As with the 1999-2000 studies, capture dates were timed to coincide with the chick rearing stage (Centre for Wildlife Ecology *unpubl. data*; Boyd *et al.* 2000, Ryder *et al.* 2001). We affixed transmitters to birds with subcutaneous anchors (Model 394; Advanced Telemetry Systems©, Isanti, Minnesota), using the protocol described in Newman *et al.* (1999), with modifications as in Ryder *et al.* (2001; see also Hull *et al.* 2000). Transmitters were held in place posterior to the anchor site using Vetbond™ tissue adhesive or marine epoxy. Each transmitter weighed approximately 2.2 g (or < 2% of the average 182 g adult; Vermeer 1981) and had an expected lifespan of approximately 45 d. Aerial detection distances for this model are described below (see methods). Captures and transmitter attachments were performed under SFU Animal Care Permit # 642B-92.

Eighteen radio-tagged Cassin's Auklets were removed from burrows containing nestlings at approximately the mid-point of the 39-45 d nestling development period. One parent from each burrow was radio-tagged. We captured birds from two plots in West Bay (14 site A and 4 from site B; Fig. 2). We captured all birds between 23:10 - 02:38h PST, and returned birds to the

burrow immediately after transmitter attachment. Nestlings from these burrows were monitored for the duration of the study to determine their individual fates.

Twenty Cassin's Auklets were captured using "pheasant" nets between 22:40 - 00:05 h PST as they returned to the colony to deliver food-loads to nestlings. To ensure we captured chick-rearing adults, only adults carrying food-loads were radio-tagged. We erected the net (approximately 15 m x 3 m) vertically between two secured plastic poles.

Handling time for all birds was 54.5 $\pm$ 5.3 (SE) minutes (minimum = 12 min, maximum = 117 min). Average handling time was 34 min for birds removed from the burrow (range 12-91 min), and 81 min for birds captured at the net (range 43-117 min). Handling time varied at the net because it captured several birds at once, which were held in bags until they could be processed. At burrows, we always handled one bird at a time and could process it immediately.

Two adults were captured in the same burrows that they had occupied in 1999. Neither bird showed evidence of previous marking (e.g. no anchor and no scar tissue was present at the attachment site; cross reference frequencies 164.773 and 164.832 from 1999, with 164.242 and 164.203 for 2001, respectively). We found the transmitter still attached (minus the antenna) on one recaptured adult (164.114) marked in 2000, but did not attempt to re-mark it. We did not recapture any previously marked birds (from 1999 or 2000) at the net site.

We assigned gender to all adults from bill depth measurements according to the criteria developed by H. Knechtel (SFU, unpubl. data) and described in Ryder *et al.* (2001).

Rhinoceros Auklets

From 1-8 July 2002, we radio-tagged 40 adult Rhinoceros Auklets at one location in South Bay (plot located behind and to the west of the research station, Fig. 2), between 23:13 - 02:20 h PST. As with Cassin's Auklets, capture dates were timed to coincide with the chick-rearing stage. Radio transmitters (Model A4410, Advanced Telemetry Systems, Isanti, MN) were attached to in the same way as for Cassin's Auklets. Each transmitter weighed ca. 7.5 g (or < 2% of the average 512 g adult; Vermeer 1981) and had an expected lifespan of 37 days. Aerial detection distances are described below (see methods). Captures and transmitter attachments were performed under SFU Animal Care Permit # 642B-92.

Of the 40 radio-tagged birds, 21 adults were captured individually with hand-held fish-landing nets (on the slope in South Bay, at the slide location just to the west of the research station) when they flew into the colony after dark. All adults captured with nets were assumed to be returning to the colony to provision chicks because they held fish in their bills. Nineteen chick-

rearing Rhinoceros Auklets were taken from burrows containing nestlings. We monitored the nestlings from these burrows to determine their individual fates.

Handling time for all birds was 25.2 ± 1.7 (SE) minutes (minimum = 11, maximum = 55). Birds that were taken from burrows (average handling time 30.0 ± 3.1 (SE) min., minimum = 16, max = 55) were returned to their burrows immediately after transmitter attachment. Birds captured using the net (average handling time 21.6 ± 1.5 (SE) min., minimum = 11, maximum = 43) were released into the air towards the sea immediately after transmitter attachment. Rhinoceros Auklets are sexually monomorphic, and gender was not assigned for Rhinoceros Auklets on Triangle Island during this study, although is has been done for Japanese Rhinoceros Auklets using discriminant functions (Niizuma 1999).

Problems attaching transmitters to Rhinoceros Auklets: Seven of 47 captured Rhinoceros Auklets did not receive radio transmitters because the subcutaneous anchor would not insert (too much resistance to anchor prong insertion), or because some birds exhibited a more "stressed" appearance (eg. rapid panting) than others. Similar problems attaching subcutaneous anchors were reported in our 2001 pilot study with four Rhinoceros Auklets on Triangle Island (K. Amey, unpubl. report). As well, in four birds, the attachment prong of the transmitter would not insert entirely (last corner of subcutaneous anchor would not insert under skin). These transmitters could not be removed after partial insertion, so we used extra glue to secure the transmitters prior to releasing the birds. On average, these four radios transmitted for 10 days, after which time they may have fallen off, or the bird may have left the colony.

Colony detection

We monitored the attendance behaviour of radio-tagged Cassin's Auklets at the colony prior to chick fledging, from 25 May to 30 July 2001, using a remote telemetry recording system (DCC II, Model D5041; Advanced Telemetry Systems Ltd.©, Isanti, Minnesota) stationed at the north end of West Bay on Triangle Island (Fig. 2). Details of the Data Collection Computer (DCC) hook-up and function are reported in Ryder *et al.* (2001). Using the same DCC, from 5 July to 15 August 2002, we monitored the attendance behaviour of radio-tagged Rhinoceros Auklets at the colony prior to chick fledging. The antenna was set up in South Bay on the roof of the research station, and the DCC receiver was inside the research station (Fig. 2).

Aerial detection

In both years, we used four-element Yagi antennae mounted to the aircraft struts for all surveys. Also, two surveyors conducted simultaneous, independent scans for all frequencies using separate receivers connected to the same set of antennae. For each aerial survey, we

used all detections for each radio-tagged bird to determine its most likely location (see Boyd *et al.* 2000 and Ryder *et al.* 2000 for a detailed description of both aerial telemetry and GIS mapping methods).

Cassin's Auklets

We conducted 5 aerial telemetry surveys from 5-7 June 2001 to locate radio-tagged birds at sea. During each survey, we flew near 3000 m altitude, at 130-140 kph, in a single-engine DeHaviland Beaver on floats. Each survey lasted ca. 4-5 h, including transit time to and from the base camps. All surveys were conducted during daylight hours when adult birds were presumed to be foraging at sea (see introduction).

We flew the initial survey on 5 June 2001 (10:00 to 16:00h) in the same area where most birds were detected in 1999 (Boyd *et al.* 2000) and 2000 (Ryder *et al.* 2001; Fig. 3A). The survey on 5 June was exploratory and the few data collected on this survey were not subsequently used to map distributions for that survey (see below; Kenward 2001, White and Garrott 1990). Using the information from 5 June, we flew a narrower exploratory grid pattern on the morning of 6 June (10:00 to 13:00h) north of Triangle Island (Fig. 3B; line transects separated by a distance of 14.5 km). After re-fuelling, we flew a similar grid pattern in the afternoon of 6 June (16:30 to 21:00h) northwest of Triangle Island (Fig. 3C; line transects separated by a distance of 9.5 km). In the morning of 7 June (09:00 to 14:00h), we flew a more focused grid pattern in the same area where most birds were located during the previous two surveys (Fig. 3D; line transects separated by a distance of 4.6 km).

Rhinoceros Auklets

We conducted 4 aerial telemetry surveys from 15-18 July 2002, using the same flight protocol as described above. We flew the initial survey around Triangle Island on 15 July 2002 (16:35h to 21:30h), with transects separated by 13 km (Fig. 4A). No birds were found in the morning of 16 July, and as a result, an exploratory flight pattern was flown on 16 July 2002 (10:00h to 14:50h; Fig. 4B). After refuelling, we flew a survey over the Scott Islands (17:00h to 21:30h; Fig. 4C), with line transects separated by 15 km. On 17 July (09:30h to 14:00h), we flew a narrower grid NW of Triangle Island (Fig. 4D), with line transects separated by 7.5 km. Flights conducted on 17 July pm (17:15h to 21:30h; Fig. 4E) and 18 July (09:00h to 13:30h; Fig. 4F) did not conform to a specific flight pattern because one antenna failed to function properly, however they were both concentrated NW of Triangle Island. On these dates, circular flight patterns were flown in the area where most birds were detected to maximize detections.

Estimating the area of telemetry survey coverage

We estimated aerial survey coverage from the maximum detection distances from the aircraft to the inferred locations of birds at sea, as described in Ryder *et al.* (2001; p. 6), on the afternoons of 6 and 7 June 2001, and for the 15-18 July 2002 surveys. The mean maximum horizontal detection distance from the aircraft to inferred locations was 7.0 km ± 3 km (95% C.I.) for the 6-7 June 2001 surveys pooled. There were no significant differences across survey dates (within years) in the mean maximum detection distances for 9 birds found on both dates (paired t-test, t = 1.09, df = 8, p = 0.31). In 2002, the mean maximum horizontal detection distance from the aircraft to inferred locations was 7.8 km ± 2.5 km (95% C.I.) for 15-17 (am) July, and 15.1 km ± 3.9 km (95% C.I.) for 17 July (pm) and 18 July. No significant differences were found in the mean detection distances for 7 birds found on two separate days (paired t-test, t = -0.078, df = 6, p = 0.94). The latter estimate (for 17 and 18 July) was different due to the loss of antenna function on one side of the aircraft. The loss of antenna function on one strut of the aircraft impaired our ability to detect birds using either antenna, as it created residual noise in the telemetry equipment. This noise masked our ability to reliably detect transmitters. Once the impairment was discovered, the faulty antenna was removed, resulting in a substantial improvement in our ability to detect birds.

In spite of the loss of antenna function, aerial detection distances in both years are similar to that of the same transmitter model (ATS 394) used in a study of Marbled Murrelets, which exceeded 10 km at flight altitudes from 1,500 to 3,000 m (Bradley *et al.* 2004). Thus, we are confident that our detection distance estimates are accurate. Using these horizontal detection distance estimates, we calculated area covered by telemetry in both years (Figs. 5A-5D for Cassin's Auklets 2001; and Figs. 6A-6F for Rhinoceros Auklets 2002). Estimated areas covered by aerial survey are detailed in Table 1.

Mapping and analyses of marine distributions

We plotted inferred at-sea locations of each radio-tagged bird using Arcview GIS software (Version 3.2; Environmental Systems Research Institute Inc.©, Redlands, California), as described in Boyd *et al.* 2000 and Ryder *et al.* 2001. Our assumptions were that (1) individuals did not move during each survey, and (2) all transmitters had an equal probability of detection. The factors that can lead to violation of these assumptions are discussed in Boyd *et al.* (2000) and Ryder *et al.* (2001).

As previously mentioned, we also assume that the marine distributions obtained from this research closely resemble the foraging locations of the study species.

Table 1. Estimated areas covered (hectares) by aerial telemetry surveys.

Date	average (ha)	minimum	maximum
6 June 2001	876,506	614,497	1,125,193
7 June 2001	871,655	571,013	1,165,004
16 July 2002 (am)	1,137,819	953,088	1,323,749
16 July 2002 (pm)	709,699	610,517	810,694
17 July 2002 (am)	912,388	652,623	1,174,677
17 July 2002 (pm)	462,886	433,128	497,015
18 July 2002	418,665	355,530	459,558

We generated home-range distributions (modified Jenrich-Turner; Jenrich and Turner 1969) for marked Cassin's Auklets on the afternoons of 6-7 June 2001. Such home-range ellipses, with a single estimation centre, require a minimum of 10-15 locations to stabilise (Kenward 2001), and ellipse centres estimated from the data may vary significantly when sample sizes are less than 40 (White and Garrott 1990). Because our Rhinoceros Auklet telemetry detections collected in 2002 were less than 10 per survey, we did not create Jenrich-Turner ellipses for this dataset. Instead, we use individual locations to represent the marine distribution of Rhinoceros Auklets.

The Arcview GIS Animal Movement Analysis Extension was used to compute Cassin's Auklet home range ellipses (Jenrich and Turner 1969, Hooge and Eichenlaub 1997). Typically, home range analyses generate ellipses for specific individuals detected on multiple occasions over time. In our modified approach, we used the inferred location of each marked bird as the sampling unit to calculate the arithmetic mean centre of activity for all birds. The survey grid flown on 5 June 2001 resulted in too few detections of birds to allow a Jenrich-Turner ellipse to be created.

RESULTS AND DISCUSSION

Colony detections

Cassin's Auklets

We activated the DCC prior to the aerial surveys, and it was used to confirm which adults were present at the colony during the telemetry flights. The DCC was active from 24 May to 30 July 2001, and birds were detected attending the colony from 24 May to 9 July 2001. Most birds that we radio-tagged returned nightly to the colony within 1-2 days following radio attachment (see Table 2). Of the 38 radio-tagged Cassin's Auklets, 25 regularly attended the colony (66%; 10 males, 12 females, and 3 undetermined sex) daily or every two days (Triangle Island Research Project, unpublished data). Nine of 38 (23%) birds either a) attended the colony for a short period of time and then were no longer detected, or b) attended at irregular intervals with long periods of absence from the colony. Irregular colony attendance behaviour has been known to reflect a handling or transmitter effect (Sohle *et al.* 2000), changes in prey distribution (Zador & Piatt 1999, Fraser *et al.* 2002), or weather events (Piatt *et al.* 1990, Weidinger 1996). Four of 38 (11%) birds were never detected following radio attachment, either at the colony or during the at-sea surveys (Table 2). Their transmitters may have failed, the birds may have died, or they may have left the study area. Of note, the estimated failure rate of the same ATS transmitters attached to Marbled Murrelets in Desolation Sound, B.C., was 5-6% in 2001 (N. Parker, SFU, pers. comm.).

We followed the nestling fates of the 18 radio-tagged adults taken from burrows. Eight chicks fledged, nine disappeared from the burrow underdeveloped (i.e. presumed to be too young to have fledged), and we discovered the nestling from one of the re-captured adults (164.203) dead in the burrow entrance 10 d after its parent was radio-tagged.

We tested for the effects of capture technique and handling time on subsequent detection rates at the colony. The proportion of returning adults taken from burrows (0.94 ± 0.11) was not significantly different from that for adults caught at the net (0.85 ± 0.17 (95% C.I); 2-tailed t-test, $t = 0.95$, $df = 36$, $p = 0.38$). Handling time did not appear to affect attendance behaviour, concurring with our results from 1999 and 2000 (Boyd *et al.* 2000, Ryder *et al.* 2001). We compared the proportion of adults subsequently returning to the colony after handling for ≤ 30 minutes versus > 30 minutes, and found no significant difference (0.92 ± 0.16 vs. 0.88 ± 0.14, respectively; 2-tailed t-test, $t = 0.45$, $df = 35$, $p = 0.71$).

Table 2. Summary of transmitter attachment dates and post-release detections of Cassin's Auklets breeding at Triangle Island, B.C. (2001).

Frequency[1]	Capture date and time	Capture Plot	Capture Method (burrow or net)	Adult Sex	Detected at colony Detected (x)	Detected at Sea	
						Detected (x)	Detection date(s) in June
.162	23 May 00:15	B	BUR		x	x	7
.203	14 May 23:32	A	BUR†	M			
.222	15 May 00:35	A	BUR	M	x	x	6,7
.242	15 May 01:07	A	BUR†	F	x	x?	6,7
.261	15 May 01:57	A	BUR	M	x	x	6,7
.282	15 May 02:38	A	BUR	M	x	x	6,7
.303	15 May 22:57	A	NET	M			
.342	15 May 23:00	A	NET	M	x•		
.362	15 May 23:10	A	NET	F	x	x	6,7
.382	15 May 23:14	A	NET		x	x	5,7
.403	15 May 23:17	A	NET	M	x	x	6,7
.423	15 May 23:30	A	NET	F	x	x	6,7
.443	16 May 22:40	A	NET	F	x	x	7
.464	16 May 22:42	A	NET	M	x	x	6,7
.483	16 May 22:46	A	NET	M			
.504	16 May 22:46	A	NET	F	x	x	7
.523	16 May 22:50	A	NET	F	x	x	6,7
.534	23 May 23:55	B	BUR	F	x	x	7
.562	19 May 23:03	A	NET		x•		
.583	20 May 23:07	A	NET	M	x	x	6
.604	20 May 23:11	A	NET	M	x	x	6,7
.644	20 May 23:15	A	NET	F	x	x	5,7
.663	20 May 23:31	A	NET	M	x	x	6,7
.680	20 May 23:31	A	NET	M	x	x	5
.702	20 May 23:33	A	NET	F			
.725	20 May 23:41	A	NET	F	x♂	x	6
.742	20 May 00:05	A	NET	M	x♂		
.781	21 May 23:10	A	BUR	F	x	x	6,7
.804	22 May 23:21	A	BUR		x•	x*	6
.822	21 May 23:25	A	BUR	F	x•		
.844	21 May 23:40	A	BUR	F	x	x	6,7
.864	21 May 23:57	A	BUR	F	x	x	6,7
.883	22 May 00:20	A	BUR	M	x♂	x	6
.902	22 May 00:38	A	BUR	M	x♂	x*	7
.923	22 May 23:44	A	BUR	F	x	x	6,7
.942	23 May 00:00	A	BUR		x	x	6
.964	23 May 23:25	B	BUR	M	x	x	6
.983	23 May 23:45	B	BUR	M	x♂		

[1] frequency prefix is 164 (Mhz)

[2] colony detection of radio-tagged individuals based on data collected with stationary DCC at colony from 25 May to 30 July, 2001. Individuals undetected at ≤1d post-attachment were considered to have abandoned the colony and/or the transmitter failed (detected = x).

• adult not detected at colony after period from 26 May to 1 June; * irregular attendance patterns

† recaptured adult from 1999; ? unable to confirm if this was a CAAU or MAMU marked with same frequency in Clayoquot Sound

♂ adult detected on ocean following confirmation it had abandoned the colony (no longer feeding the nestling)

Rhinoceros Auklets

In 2002 the DCC was activated prior to aerial surveys and recorded adult Rhinoceros Auklets attending the colony. The DCC was active from 5 July to 15 August 2002, and birds were detected attending the colony from 5 July to 31 July. We detected all (40/40) Rhinoceros Auklets at the colony at least once (Table 3), and adults returned to the colony for an average of 19.5 days after radio-tagging. Of these, 12 (30%) returned regularly to the colony, 19 (47.5%) attended the colony irregularly (with skips of 2-3 days between bouts of regular daily shifts), 8 (20%) returned a few times before disappearing, and 1 (2.5%) disappeared after attending the colony only once, 5 days after radio-tagging. The high frequency of irregular shifts may be a normal pattern in Rhinoceros Auklet breeding effort, possibly due to daily variation in provisioning activity (Creelman and Storey 1991, Fraser *et al.* 2002), or to variation in chick provisioning due to variation in adult condition (Fraser *et al.* 2002). Colony attendance has also been found to vary with weather (Piatt *et al.* 1990, Weidinger 1996), or with prey availability, which may be patchily-distributed, unpredictable, or in short supply (Zador and Piatt 1999, Kitaysky *et al.* 2000).

The radio transmitters themselves may have affected colony attendance patterns (Sohle *et al.* 2000), but because we did not monitor colony attendance in unmarked control groups, we were unable to address this question. However, we did assess the number of days of attendance at the colony subsequent to radio-tagging; the number of days detected at the colony did not differ significantly between adults taken from burrows (9.85 days $\pm$ 1.15 SE) versus those caught in the net (7.95 days $\pm$ 0.87 SE; 2-tailed t-test, $t = 1.33$, $p = 0.19$, $df = 38$). Handling time did not differ between those that attended regularly (25.5 $\pm$ 2.3 min) and those that attended irregularly (24.7 $\pm$ min; 2-tailed t-test, $t = 2.02$, $p = 0.85$, $df = 36$). Because of the problems we encountered while attaching radio transmitters, we suggest that in future, researchers attaching radio transmitters to Rhinoceros Auklets have additional training for minor surgical procedures on birds.

Nineteen chicks, from the 19 radio-tagged adults taken from burrows, were monitored until 1 August 2002. Three were found dead in the burrow, one was confirmed to fledge, two had unknown fates (disappeared prematurely from the burrow), and 13 were last seen in the burrow and were near fledging mass. All radio-tagged birds apparently left the colony (i.e. were last detected at the colony by the DCC) before the chicks left the burrow; this occurred on average 5 days before our last chick monitoring activity.

Table 3. Summary of transmitter attachment dates and post-release detections of Rhinoceros Auklets at Triangle Island, 2002.

Frequency *	Capture Date	Capture Time	Capture Method	Detected at Colony: Detected (x)	Detected at Colony: Number of Days	Detected at Sea: Detected (x)	Detected at Sea: Dates (July)
.033	1-Jul	23:30	BUR	X	8		
.056	2-Jul	00:24	NET	X	12		
.072	3-Jul	00:24	BUR	X	17	X	17
.093	3-Jul	00:24	BUR	X	17	X	17,18
.111	3-Jul	01:15	BUR	X	6		
.133	3-Jul	01:00	BUR	X	1		
.151	3-Jul	01:25	BUR	X	2	X	18
.174	3-Jul	02:15	BUR	X	11		
.192	3-Jul	02:20	BUR	X	14		
.212	4-Jul	00:30	BUR	X	5		
.233	4-Jul	00:30	BUR	X	16	X	16
.251	4-Jul	00:55	BUR	X	17		
.271	4-Jul	01:00	BUR	X	13	X	17,18
.294	4-Jul	01:24	BUR	X	10	X	16
.313	4-Jul	01:20	BUR	X	11	X	17,18
.334	4-Jul	01:43	BUR	X	7	X	15,16
.355	4-Jul	01:53	BUR	X	10	X	17
.370	4-Jul	23:34	NET	X	14	X	16
.393	5-Jul	00:03	NET	X	13	X	17,18
.414	5-Jul	00:15	NET	X	6	X	17
.434	7-Jul	00:10	NET	X	13		
.454	5-Jul	00:32	NET	X	9		
.474	5-Jul	01:30	BUR	X	4		
.492	5-Jul	01:57	NET	X	8		
.513	6-Jul	23:27	NET	X	13		
.533	8-Jul	23:42	NET	X	11		
.553	6-Jul	23:45	NET	X	8		
.573	7-Jul	00:50	NET	X	7	X	17,18
.592	7-Jul	01:16	NET	X	10		
.613	7-Jul	01:25	NET	X	11	X	15
.633	7-Jul	01:00	NET	X	2		
.653	7-Jul	23:26	NET	X	4	X	18
.674	7-Jul	23:13	NET	X	4		
.694	7-Jul	00:45	BUR	X	8		
.713	7-Jul	23:30	NET	X	2		
.732	7-Jul	00:27	BUR	X	10	X	18
.753	8-Jul	23:55	NET	X	5		
.774	8-Jul	00:25	NET	X	2		
.794	8-Jul	23:55	NET	X	9		
.814	8-Jul	23:50	NET	X	4	X	17,18

*prefix is 165.XXX

At-sea detections

Cassin's Auklets

We detected 28 of 37 (76%) radio-tagged Cassin's Auklets at sea on at least one occasion (Table 2). We detected one bird (164.242) in the nearshore environment on the north-central coast of Vancouver Island but could not confirm that it was a Cassin's Auklet; this individual may have been a missing Marbled Murrelet tagged with the same frequency in Clayoquot Sound in May 2001 (Centre for Wildlife Ecology, *unpublished data*), and was excluded from subsequent analyses.

On our initial 5 June 2001 exploratory survey, only 3 (8%) marked birds were detected at sea. In the morning of 6 June, we detected 10 (27%) marked birds at-sea; in the afternoon of 6 June, we detected 15 (41%) marked birds; and on 7 June, we detected 22 (60%) marked birds (see Table 4). The patterns found on 6 and 7 June (Fig. 7) represent the marine distributions of Cassin's Auklets on those days during the chick-rearing period.

Table 4 shows mean water depth and distance from Triangle Island of all detected Cassin's Auklets. Male Cassin's Auklets were found significantly closer to the colony (54.07 km $\pm$ 6.35 SE) than females (81.07 km $\pm$ 4.9 SE; $t = -3.44$, $P < 0.003$, $df = 21$). Distances did not differ significantly between Cassin's Auklets attending versus not attending the colony, nor between birds from different parts of the colony.

Table 4. Distance from Triangle Island and water depth of marine telemetry detections of Cassin's Auklets in 2001 and Rhinoceros Auklets in 2002.

Species	Date	Mean Distance (km)	Maximum Distance (km)	Mean Depth (m)	Sample size
Cassin's Auklet	6 June am	55.36 $\pm$ 9.60	95.25	330.74 $\pm$ 92.03	10
	6 June pm	57.01 $\pm$ 5.83	82.17	594.49 $\pm$ 111.76	15
	7-Jun	80.14 $\pm$ 6.15	113.30	888.85 $\pm$ 140.14	22
Rhinoceros Auklet	16-Jul	20.91 $\pm$ 6.48	33.94	103 $\pm$ 25.61	4
	17 July am	58.10 $\pm$ 0.85	62.27	174.05 $\pm$ 17.12	6
	17 July pm	66.08 $\pm$ 3.5	73.53	137.11 $\pm$ 32.84	8
	18 July am/pm	71.42 $\pm$ 1.68	78.20	97.52 $\pm$ 8.78	9

Compared to previous years, when 96% (1999) and 91% (2000) of the radio-tagged bird were detected at sea, detection rates of radio-tagged Cassin's Auklets in 2001 were low. Factors contributing to this may have been partly methodological, but also due to an apparent change in the distribution of the birds at sea in 2001. In 2001, two observers (instead of one in previous years) recorded telemetry signals and this required additional equipment (eg. receivers, coaxial linkages) that introduced additional noise into the system, possibly reducing the detection probability and detection distance of individual transmitters. As well, the marine distribution of Cassin's Auklets changed from that seen in 1999/2000, requiring a larger exploratory survey to locate the birds at sea in 2001, and reducing the time that could be spent locating birds on replicate surveys. Finally, in 2001, the birds seemed more evenly distributed across the seascape, compared to the clumped distribution seen in 1999/2000. A more dispersed distribution lowered the probability of detecting single individuals.

Rhinoceros Auklets

We detected 17 (43%) individual radio-tagged Rhinoceros Auklets at sea on at least one occasion (Table 3). In the afternoon of 16 July, we detected 4 (10%) marked birds at sea; on the morning of 17 July, we detected 6 (15%) marked birds; in the afternoon of 17 July, we detected 8 (20%) marked birds; and on 18 July, we detected 9 (23%) marked birds. The patterns found on 16-18 July (Fig. 9) represent the marine foraging distribution of Rhinoceros Auklets on those days during the chick-rearing period.

Table 4 shows mean water depth and distance from Triangle Island, of all detected Rhinoceros Auklets. There was no difference between at-sea distributions of Rhinoceros Auklets attending versus not attending the colony. Sex was not determined, so we could not assess the relative at-sea distributions of males versus females.

Compared to Cassin's Auklets, of which 76-95% of individuals were detected at sea over three years, marine detectability of Rhinoceros Auklets (43% overall) was low. This number of at-sea detections contrast sharply with our 75%-detection rate of Rhinoceros Auklets at the colony on at least an irregular basis (see section above), suggesting that many of our radio tagged auklets were feeding undetected. This difference in detectability may have occurred if the Rhinoceros Auklets were scattered over a larger foraging area than Cassin's Auklets (as is likely; G. Kaiser pers. comm.), and thus distributed less densely across the marine landscape than Cassin's Auklets; ultimately, we do not know the reasons for this difference.

Foraging ranges and distributions

Cassin's Auklets

In 2001, we found that most Cassin's Auklets detected at-sea on the 6 June and 7 June were concentrated in an area ca. 58 km NW of Triangle Island. This was a substantial shift from the marine distributions in both 1999 and 2000 (see Boyd *et al.* 2000, Ryder *et al.* 2001), when Cassin's Auklets were consistently concentrated 50-60 km SW of Triangle Island. This inter-annual distribution shift from south to north is corroborated by the marine detections of the same individual, found southwest of Triangle Island in 1999 but northwest in 2001 (Fig. 8).
The Jenrich-Turner 95% probability ellipse for the morning of 6 June 2001 covered an area of 624, 038 ha with an arithmetic mean point 52 km NW of Triangle Island. The 95% probability ellipse for the afternoon of 6 June 2001 covered an area of 457, 383 ha with an arithmetic mean point 55 km NW of Triangle Island. The 95% probability ellipse for 7 June 2001 covered an area of 1, 408, 699 ha with an arithmetic mean point 70 km NW of Triangle Island (Fig.10). Between 6 June and 7 June the estimated centre of distribution shifted ca. 15 km to the NW. Other planktivorous auklets, such as the Least and Crested Auklets, had similar foraging radii to that found in this study (up to 56 km, Obst *et al.* 1995; and up to 110 km, Hunt *et al.* 1993). In contrast to 1999 and 2000, when the majority of marked Cassin's Auklets foraged seaward of the 1000 m shelf break isobath, only 6 of 48 detections were seaward of this isobath 6-7 June 2001; the remaining birds were over the shelf, or east of the 1000 m isobath, in water that averaged 723 $\pm$ 88 m (range 27 – 2185 m) in depth, compared to 1500-2000 m depth in previous years.

Rhinoceros Auklets

On 16 July 2002, four Rhinoceros Auklets were found in an area roughly 19 km SE of Triangle Island (Fig. 9). On 17-18 July, the majority of birds were concentrated in an area about 64 km NW of Triangle Island (Fig. 9). However, this area was not surveyed prior to 17-18 July, so the apparent shift in distribution may be an artefact of sample size, patchily-distributed birds, or the change to survey location in an attempt to find more birds. Different individuals were used to create daily distributions, and it could be that different birds go to different foraging places. Corroborating this, the four birds detected SW of the colony (16 July) were not subsequently detected NW of the colony on 17 or 18 July surveys.
Foraging distributions for the Rhinoceros Auklets at Triangle appear to be similar to those reported for other medium- to large-sized alcids (Wanless *et al.* 1990, Hatch *et al.* 2000). Kato *et al.* (2003) estimated a similar average maximum foraging range for Rhinoceros Auklets from

Teuri Island (Japan), to be 87 km (164 km maximum). Radio-tagged Rhinoceros Auklets were in water 122 ± 12 m (range 35-285) deep, most of them eastward of the 200 m shelf break (as in Fig. 9).

A portion of the apparent shifts of at-sea distributions, for both the Cassin's and Rhinoceros Auklets, may also be explained by differences in our sampling design rather than being solely attributable to individual movements. As discussed in our two previous studies (Boyd *et al.* 2000, Ryder *et al.* 2001), several factors that affect quantity and quality of the telemetry signals received may impair our ability to accurately estimate a single best location. Large aerial sampling grids provide extensive survey coverage, but there is a reduced probability of either a) detecting an individual, or b) plotting the location of an individual accurately. Our survey grids are designed to cover large areas of ocean, and exact locations are difficult to pinpoint as we would have to break transect and circle individual marked birds at low altitude, an approach not feasible for long distance offshore flights. However, a location accuracy of 1-2 km is still sufficient for examining broad scale patterns of distribution.

Because data for the at-sea distributions of the planktivorous Cassin's Auklet and the piscivorous Rhinoceros Auklet were collected in different years, we felt it would not be valid to make a direct comparison between each species' distribution. Cassin's Auklets were generally located at sea in deeper water, west of the Rhinoceros Auklets' locations, and were more closely associated with the 1000-m isobath. Cassin's Auklets prey heavily on pelagic crustaceans (eg. *Neocalanus* copepods), which are more abundant along, or seaward of, the continental shelf (Mackas *et al.* 2001); Rhinoceros Auklets feed on less pelagic prey, that are more abundant within 200-m isobath (Logerwell and Hargreaves 1996). Logerwell and Hargreaves (1996) found that Cassin's Auklets were consistently more abundant seaward of, while piscivorous murres and shearwaters were consistently more abundant inshore of, the 200-m isobath. Thus, despite our inability to make robust spatio-temporal comparisons of foraging locations, our data may reflect a true difference between the marine distributions of Rhinoceros Auklets and Cassin's Auklets breeding at Triangle Island.

Previous telemetry studies (Boyd et al. 2000, Ryder *et al.* 2001, J. Adams, USGS-BRD, unpubl. data) have found that Cassin's Auklets use the same general foraging area in successive years. However, foraging locations are likely to vary with the oceanographic processes (eg. fronts and upwelling) that influence aggregations of prey (Hunt 1997, Russell *et al.* 1999, Lilliendahl *et al.* 2003). In our Cassin's Auklet study, oceanographic factors (fronts or upwelling) affecting the distribution of copepods appeared to change between 2000 and 2001, causing

Cassin's Auklets to move from foraging SW of Triangle Island in 1999 and 2000, to NW of the island in 2001.

Summary

As in 1999 and 2000, radio-tagged Cassin's Auklets in 2001 were found near the 1000-m isobath, but were significantly further north (ca. 100 km) than in previous years. We detected 76% of the radio-tagged birds at-sea on at least one occasion. We found that male Cassin's Auklets foraged significantly closer to the colony than females. In 2002, the majority of radio-tagged Rhinoceros Auklets were found 64 km NW of Triangle Island, near the 200-m isobath. We detected 43% Rhinoceros Auklets at sea at least once. The more inshore marine distribution of Rhinoceros Auklets compared to Cassin's Auklets has been recorded at other locations in British Columbia, and likely represents a consistent pattern between these species. At sea, we detected some movement of individuals between survey periods. However, on a large geographic scale we argue that these localized individual movements are insignificant in the context of identifying key areas for marine conservation.

Our results from 2001 were very different from the pelagic distribution patterns of Cassin's Auklet observed 1999 and 2000, when birds were concentrated 50-60 km SW of Triangle Island. This suggests that the oceanographic factors (fronts or upwelling) affecting the distribution or availability of copepods changed significantly. These findings are useful for future marine conservation efforts, and outline the potential for variable oceanographic conditions to affect seabird foraging in this highly dynamic system. Thus, effective marine conservation planning and MWA reserve design require multiple years of data collection, allowing a solid basis for making inferences about how seabird distributions vary from year to year. As well, multiple years of seabird distribution data are crucial to managers making decisions that will mitigate threats to seabirds from non-renewable resource exploration and development, fisheries impacts, and other environmental impacts such as oil spills.

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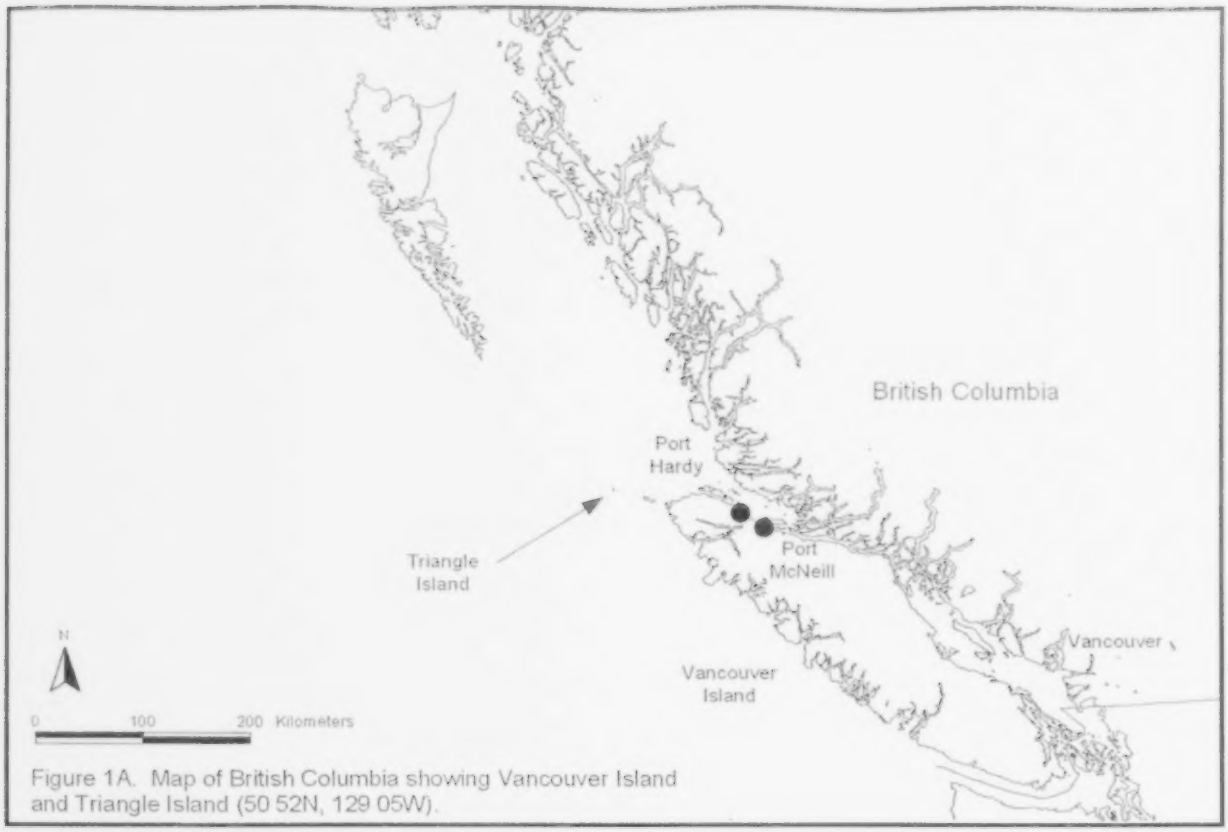

Figure 1A. Map of British Columbia showing Vancouver Island and Triangle Island (50 52N, 129 05W).

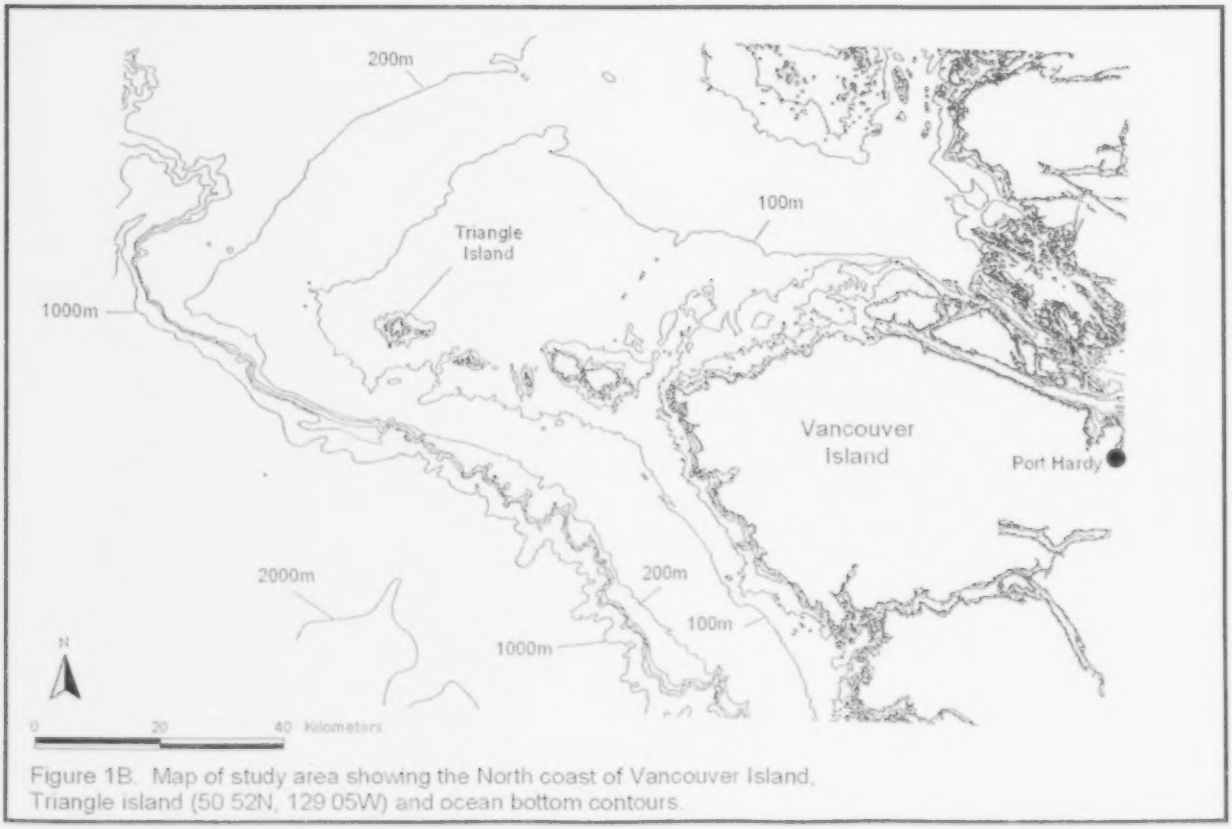

Figure 1B. Map of study area showing the North coast of Vancouver Island, Triangle island (50 52N, 129 05W) and ocean bottom contours.

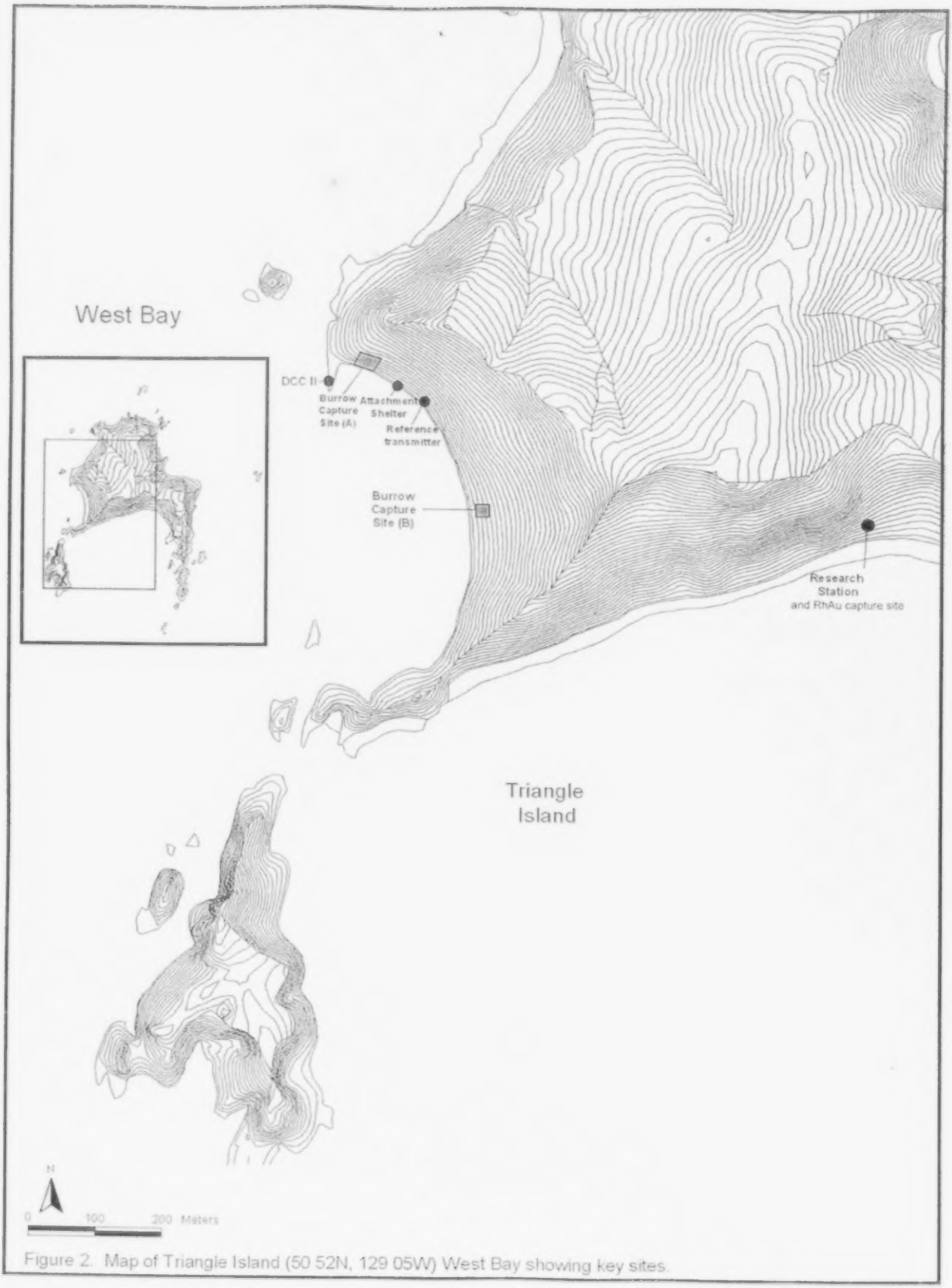

Figure 2. Map of Triangle Island (50 52N, 129 05W) West Bay showing key sites.

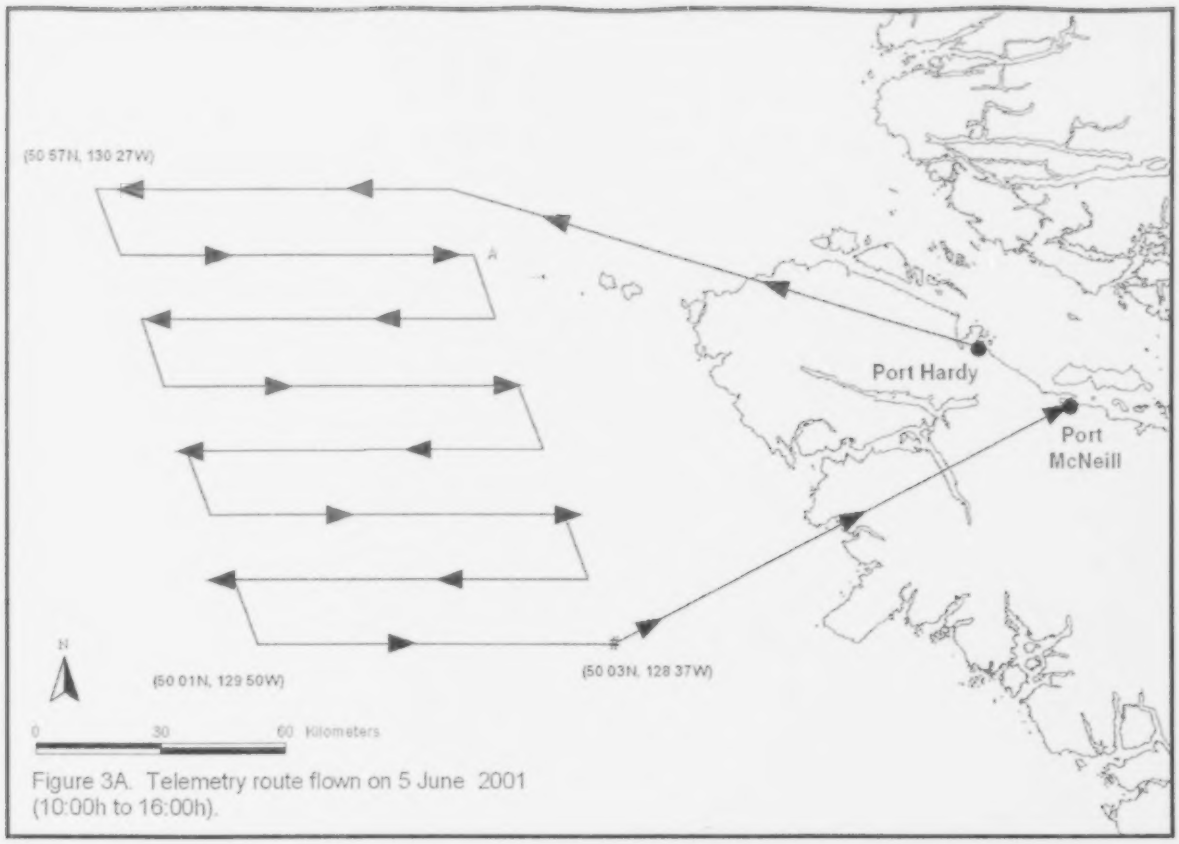

Figure 3A. Telemetry route flown on 5 June 2001 (10:00h to 16:00h).

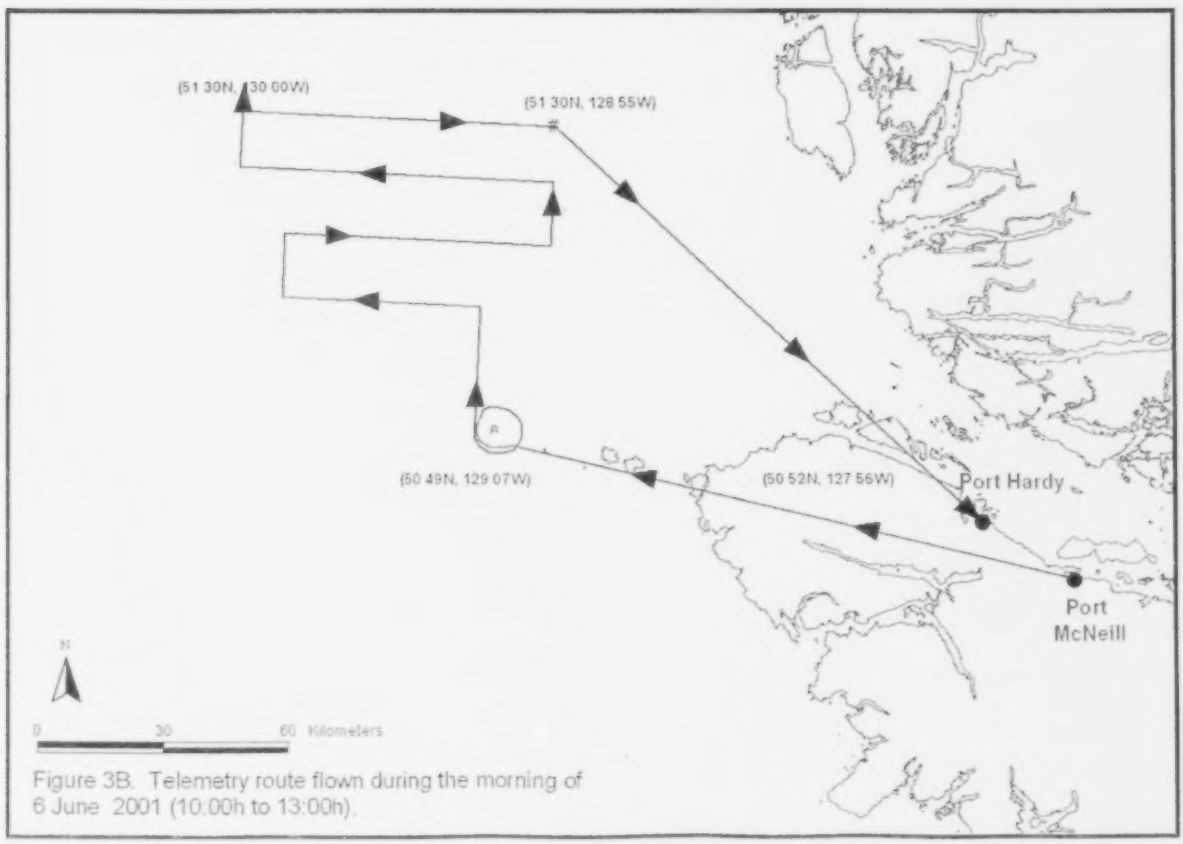

Figure 3B. Telemetry route flown during the morning of 6 June 2001 (10:00h to 13:00h).

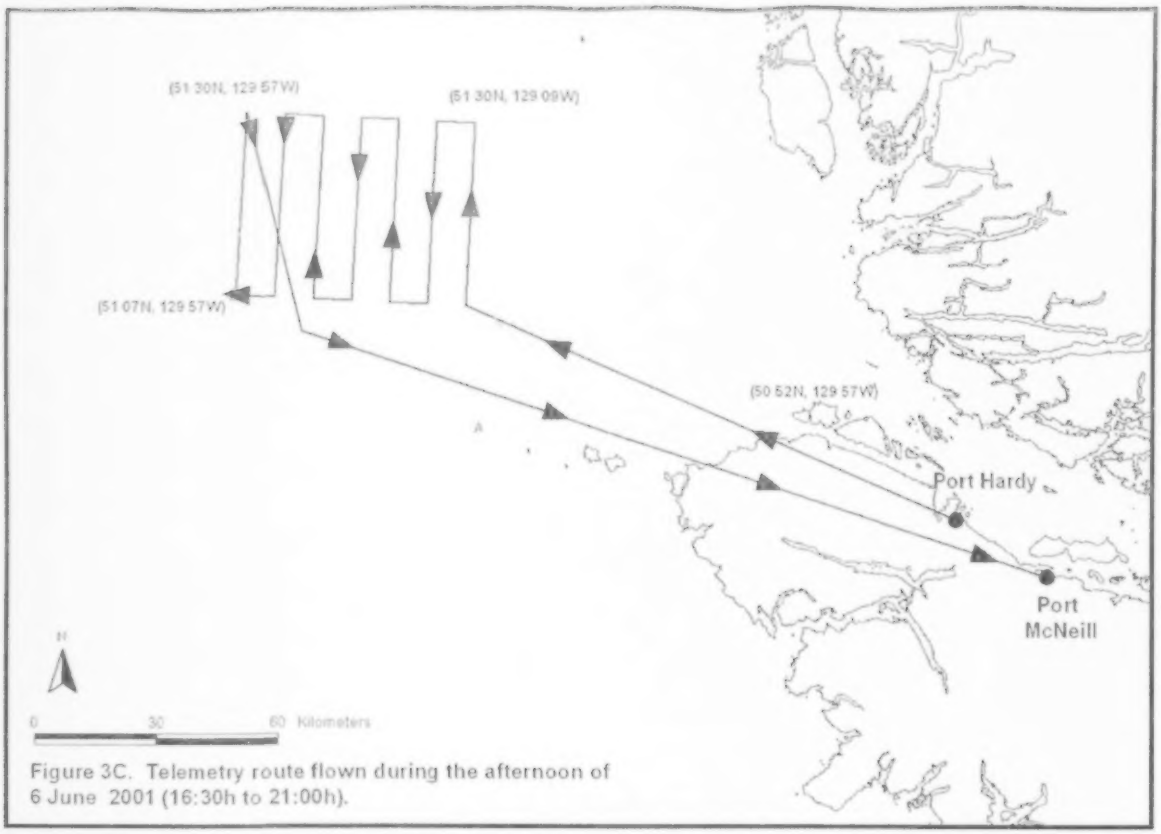

Figure 3C. Telemetry route flown during the afternoon of 6 June 2001 (16:30h to 21:00h).

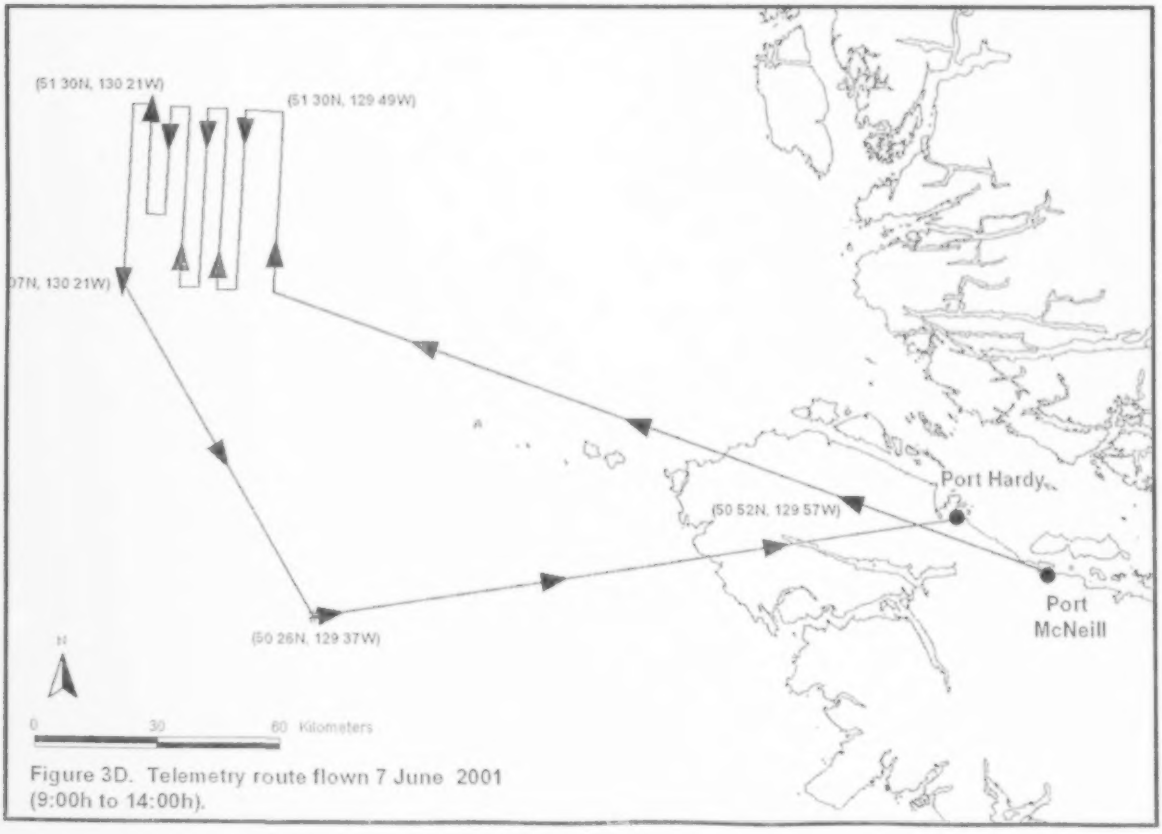

Figure 3D. Telemetry route flown 7 June 2001 (9:00h to 14:00h).

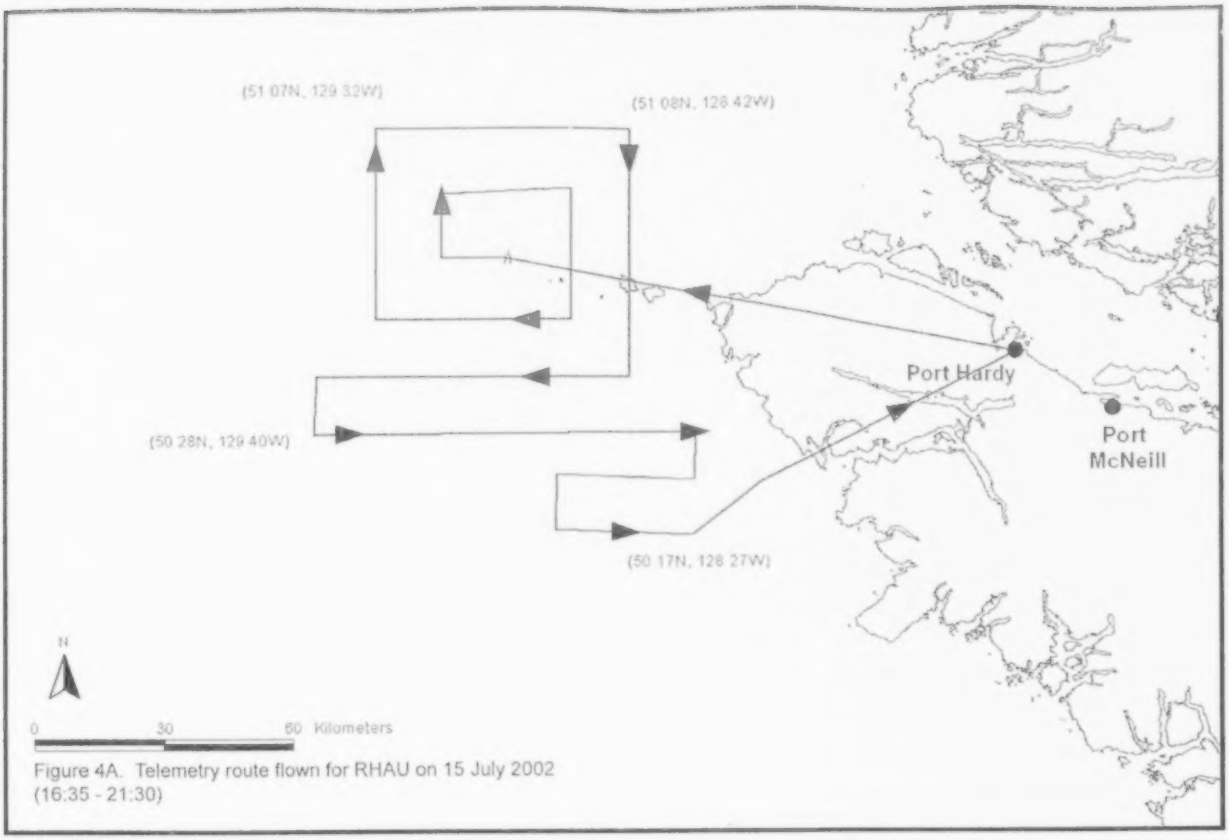

Figure 4A. Telemetry route flown for RHAU on 15 July 2002 (16:35 - 21:30)

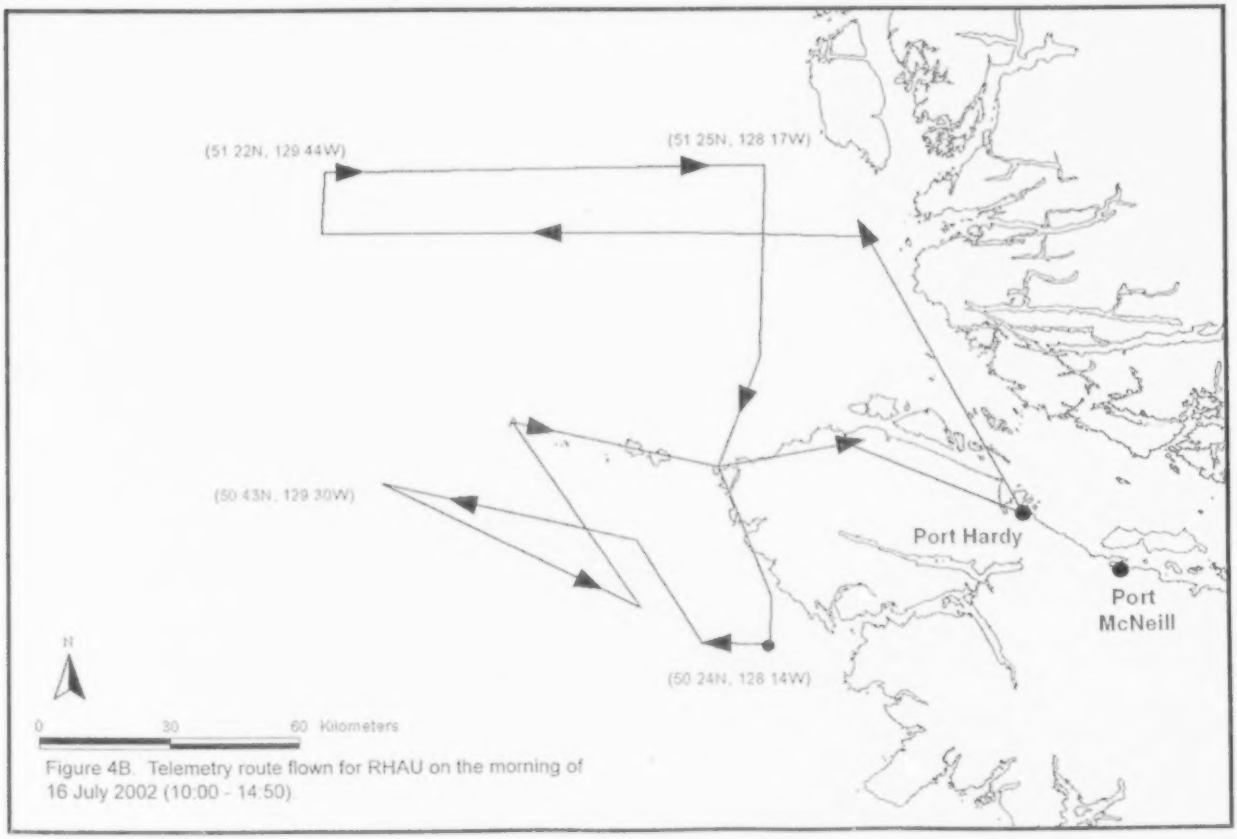

Figure 4B. Telemetry route flown for RHAU on the morning of 16 July 2002 (10:00 - 14:50).

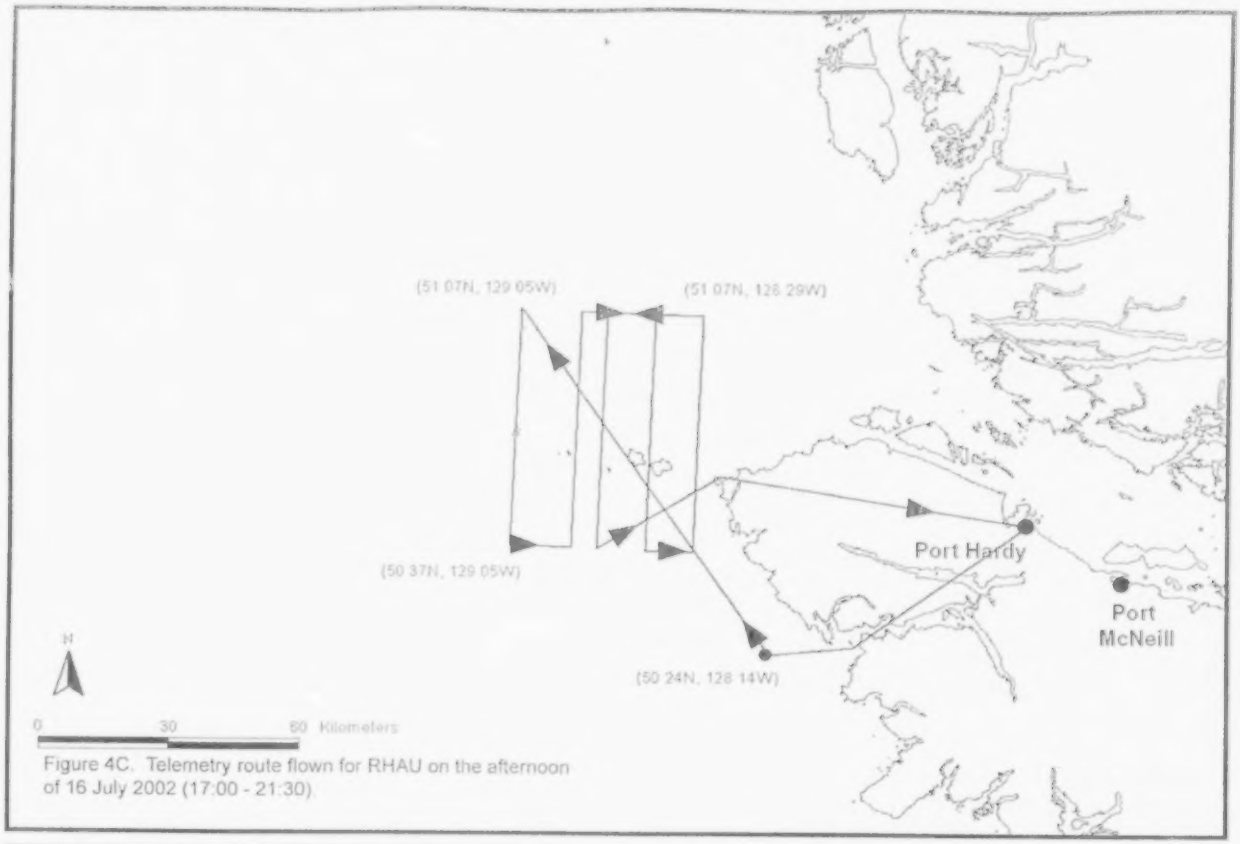

Figure 4C. Telemetry route flown for RHAU on the afternoon of 16 July 2002 (17:00 - 21:30).

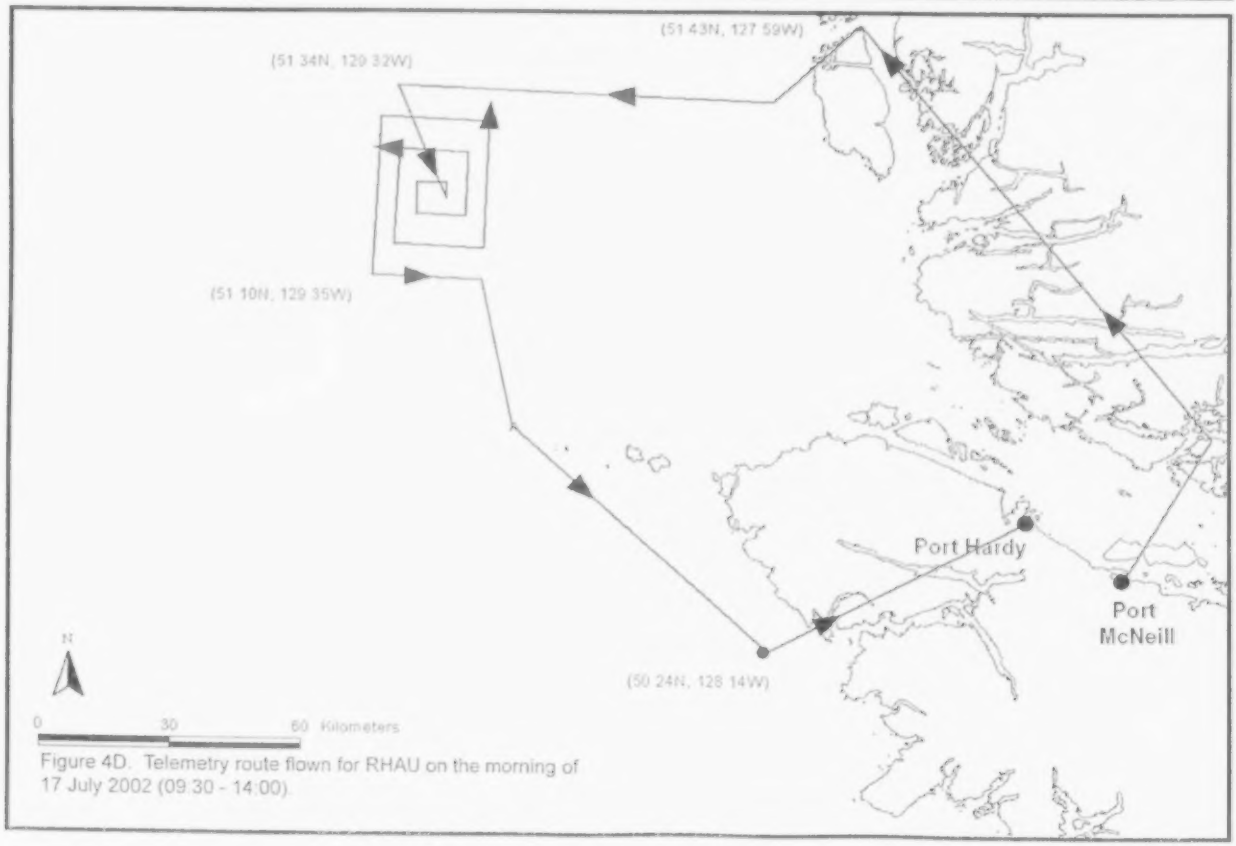

Figure 4D. Telemetry route flown for RHAU on the morning of 17 July 2002 (09:30 - 14:00).

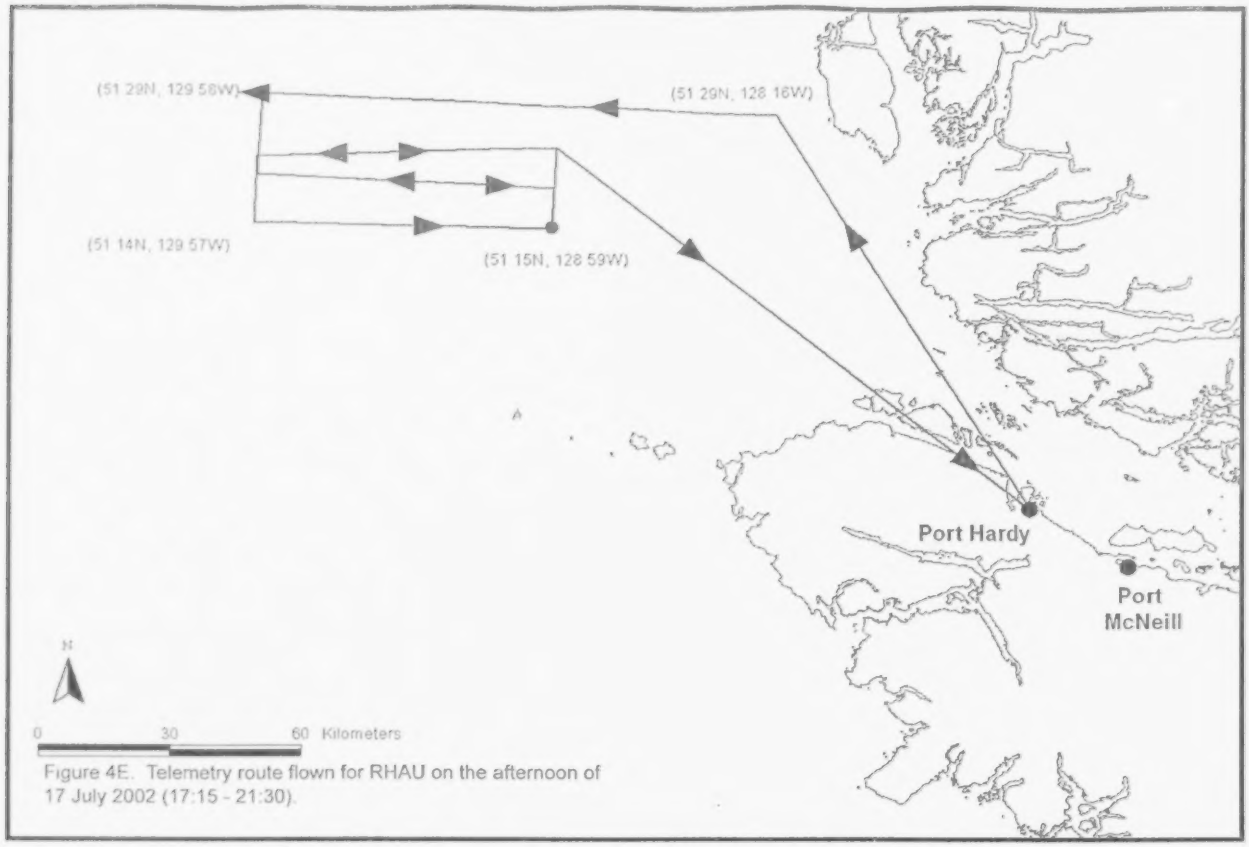

Figure 4E. Telemetry route flown for RHAU on the afternoon of 17 July 2002 (17:15 - 21:30).

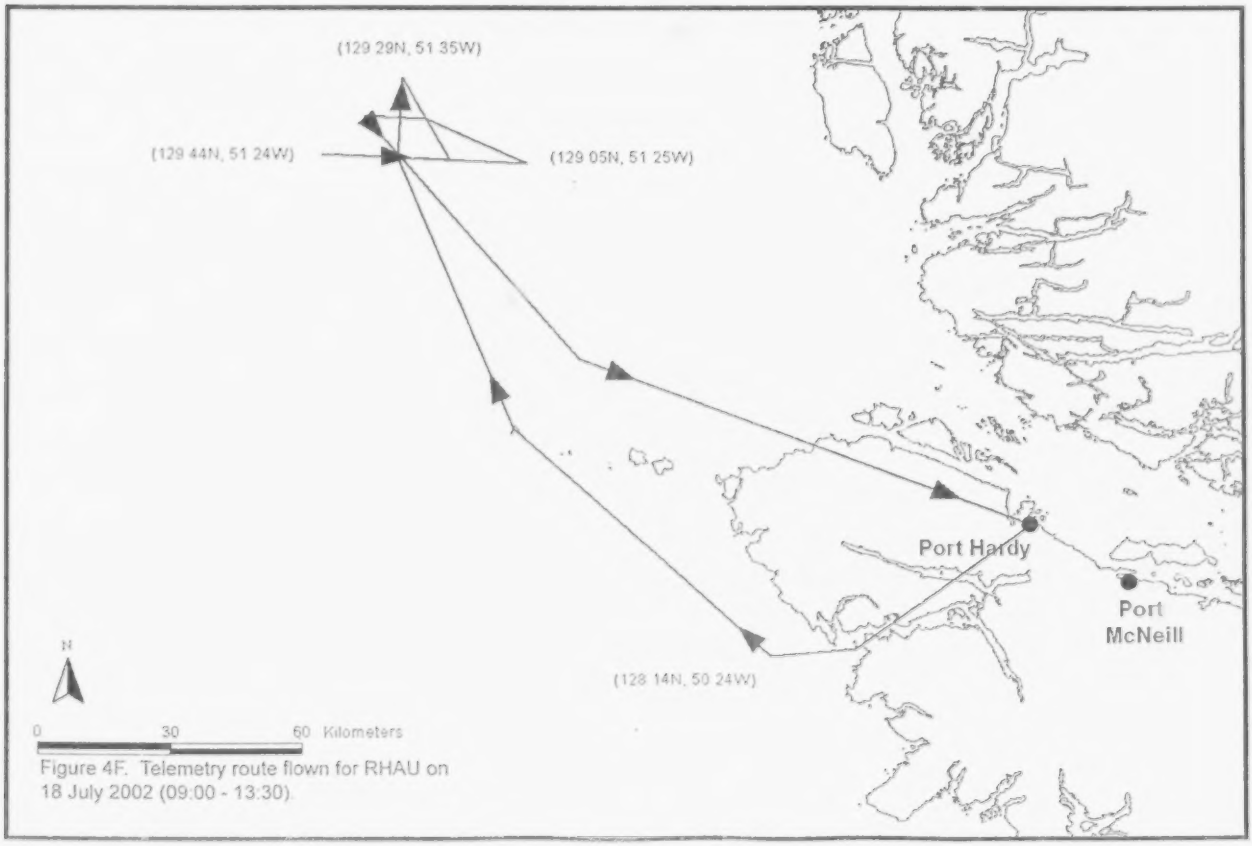

Figure 4F. Telemetry route flown for RHAU on 18 July 2002 (09:00 - 13:30).

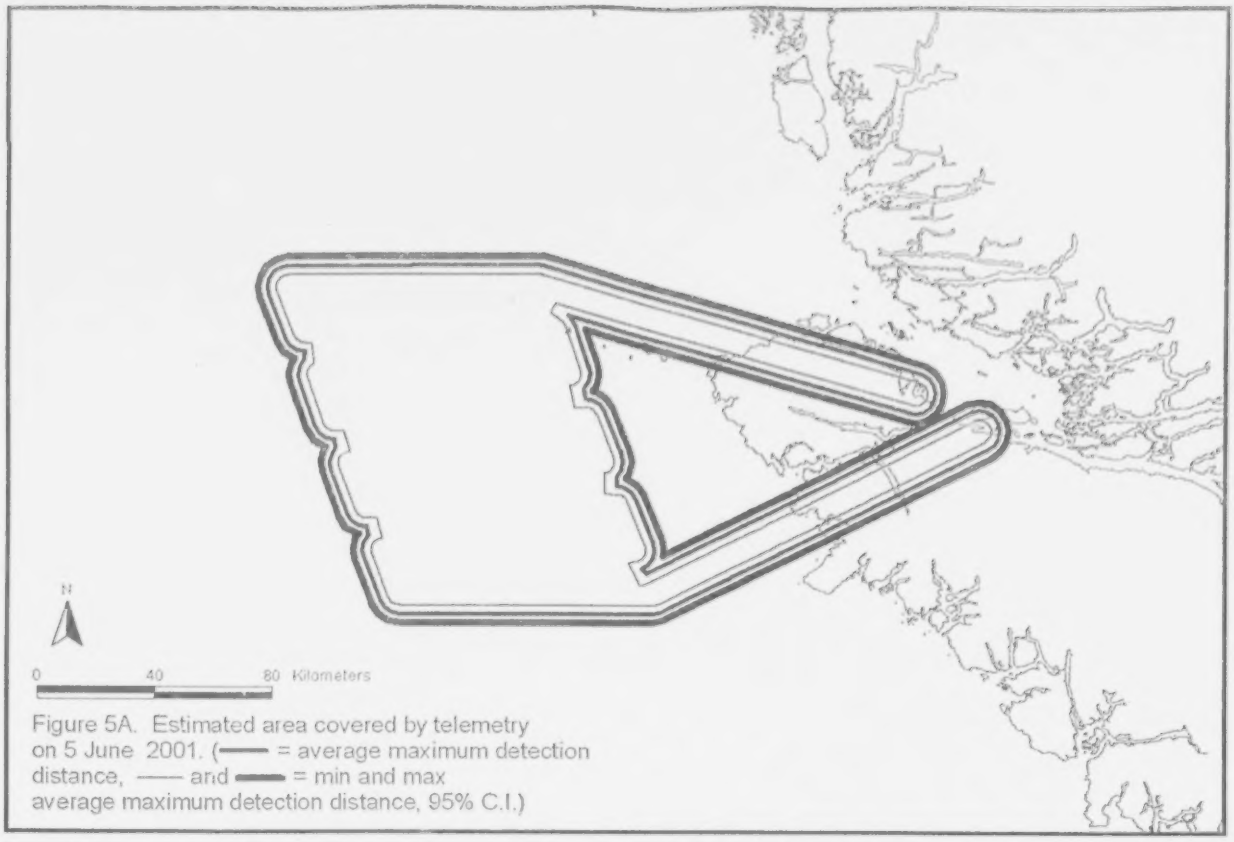

Figure 5A. Estimated area covered by telemetry on 5 June 2001. (—— = average maximum detection distance, —— and —— = min and max average maximum detection distance, 95% C.I.)

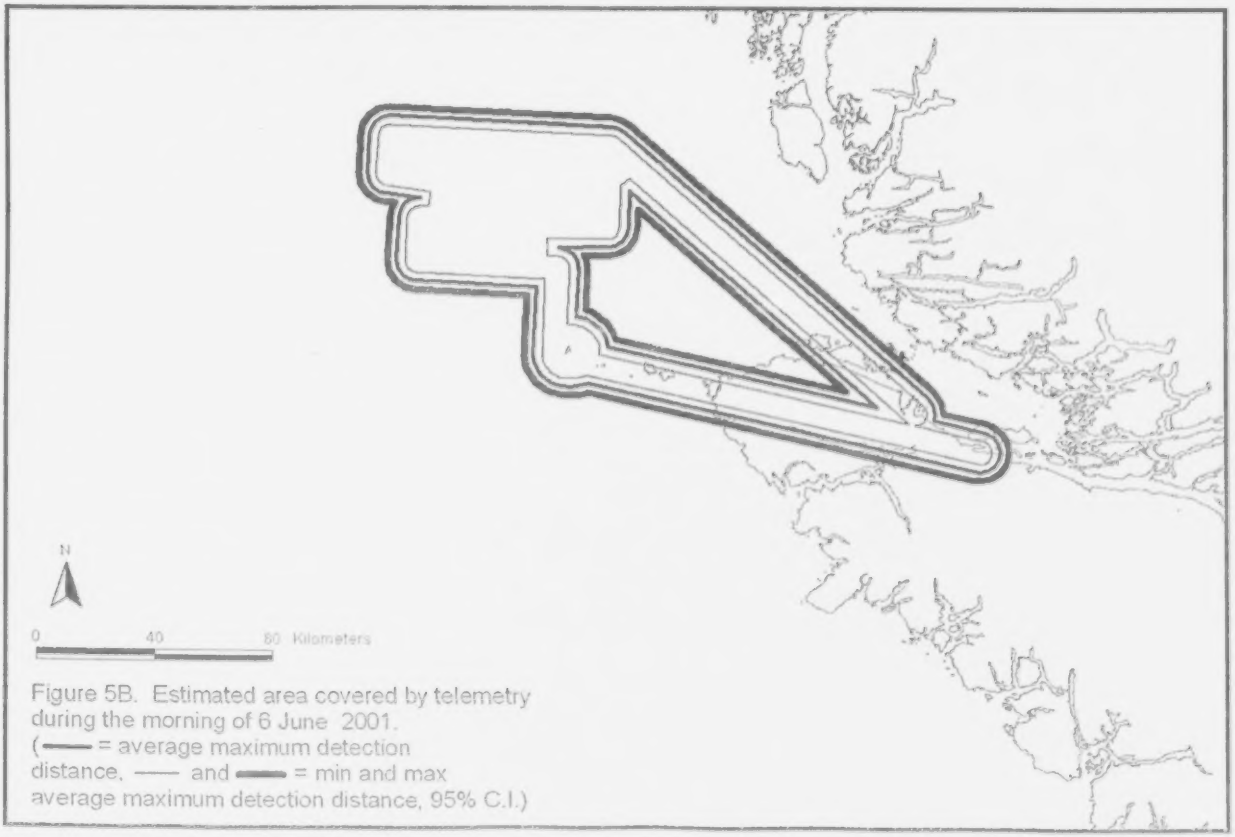

Figure 5B. Estimated area covered by telemetry during the morning of 6 June 2001. (—— = average maximum detection distance, —— and —— = min and max average maximum detection distance, 95% C.I.)

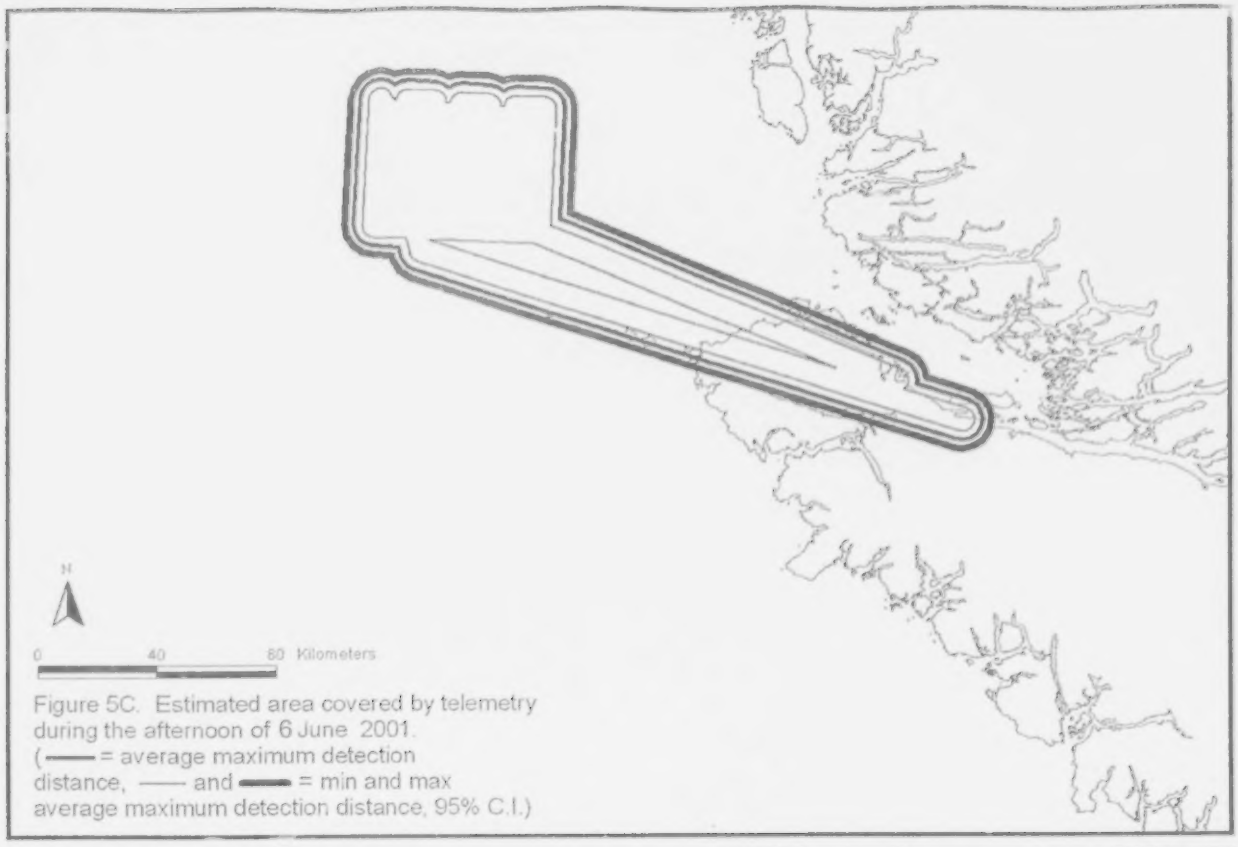

Figure 5C. Estimated area covered by telemetry during the afternoon of 6 June 2001. (—— = average maximum detection distance, —— and ▬ = min and max average maximum detection distance, 95% C.I.)

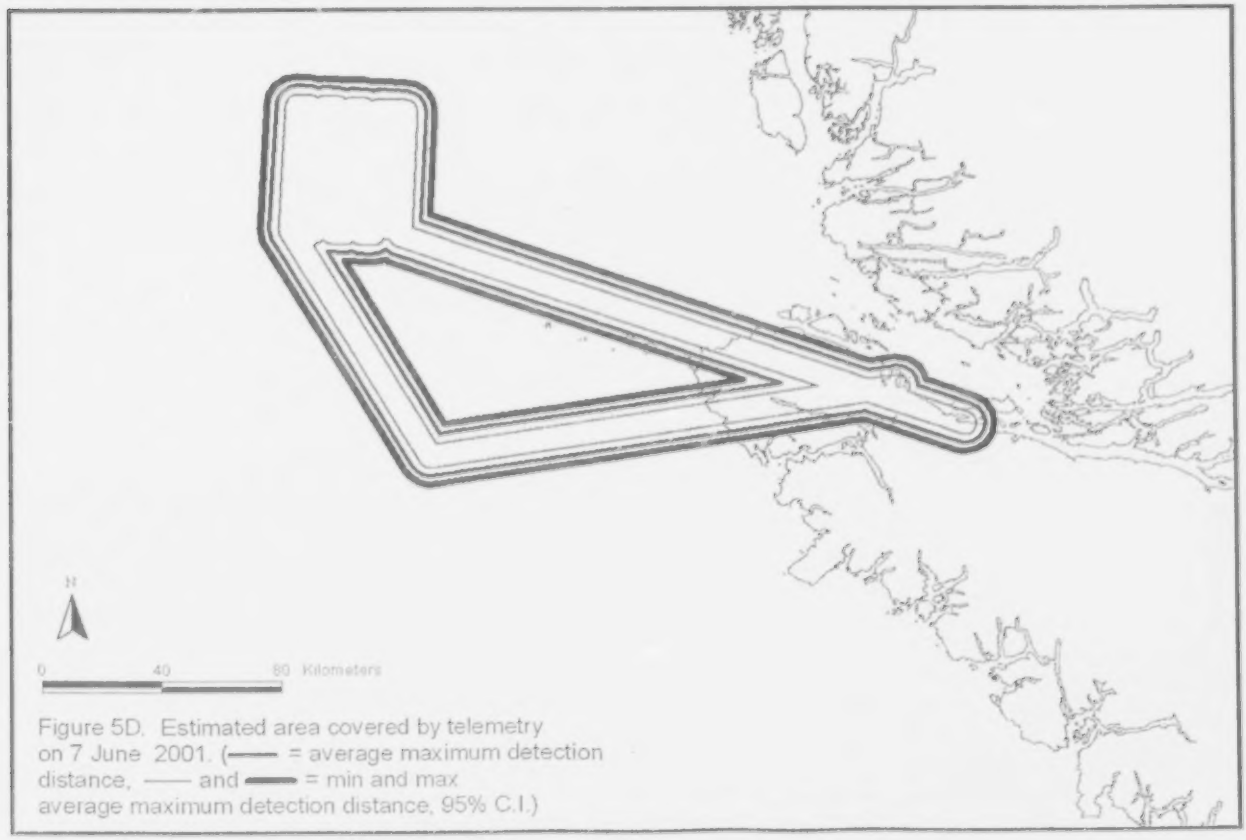

Figure 5D. Estimated area covered by telemetry on 7 June 2001. (—— = average maximum detection distance, —— and ▬ = min and max average maximum detection distance, 95% C.I.)

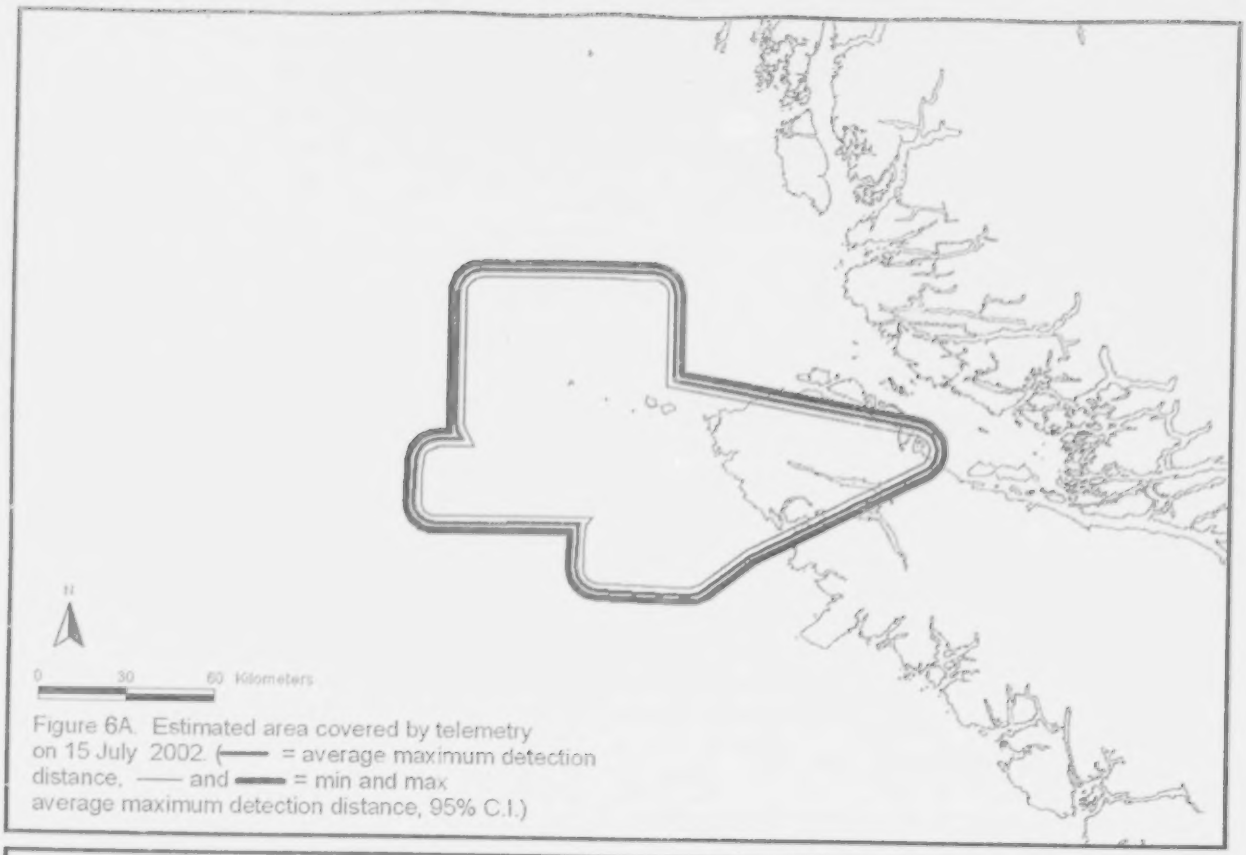

Figure 6A. Estimated area covered by telemetry on 15 July 2002. (—— = average maximum detection distance, —— and ▬ = min and max average maximum detection distance, 95% C.I.)

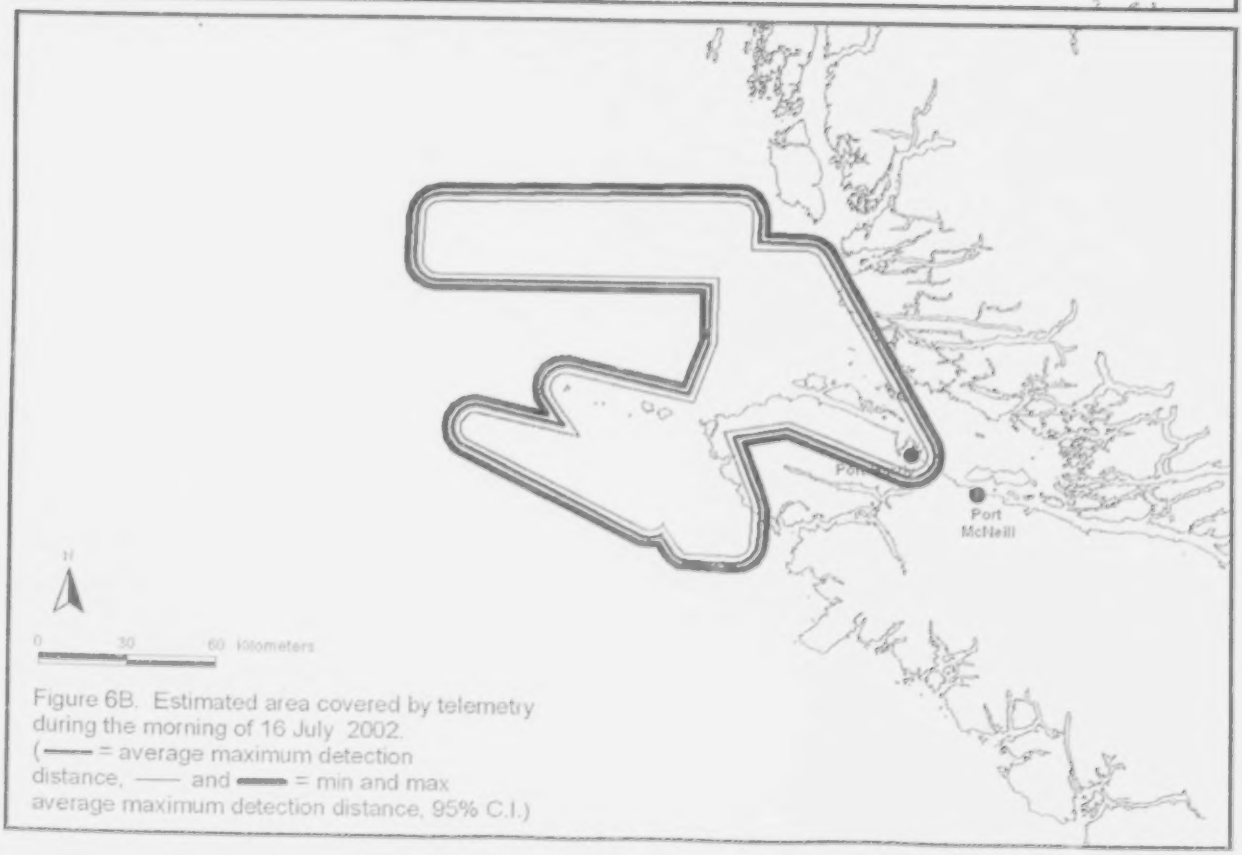

Figure 6B. Estimated area covered by telemetry during the morning of 16 July 2002. (—— = average maximum detection distance, —— and ▬ = min and max average maximum detection distance, 95% C.I.)

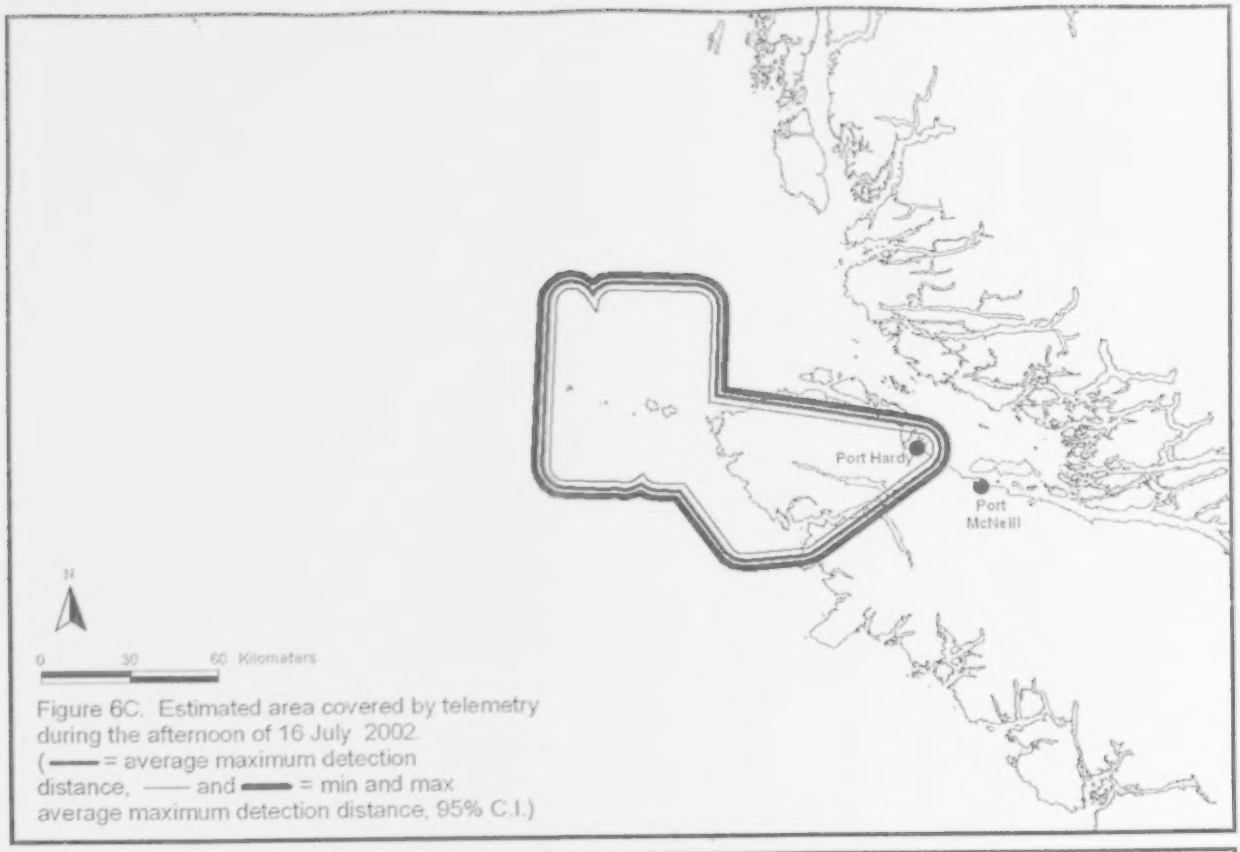

Figure 6C. Estimated area covered by telemetry during the afternoon of 16 July 2002. (—— = average maximum detection distance, —— and ▬ = min and max average maximum detection distance, 95% C.I.)

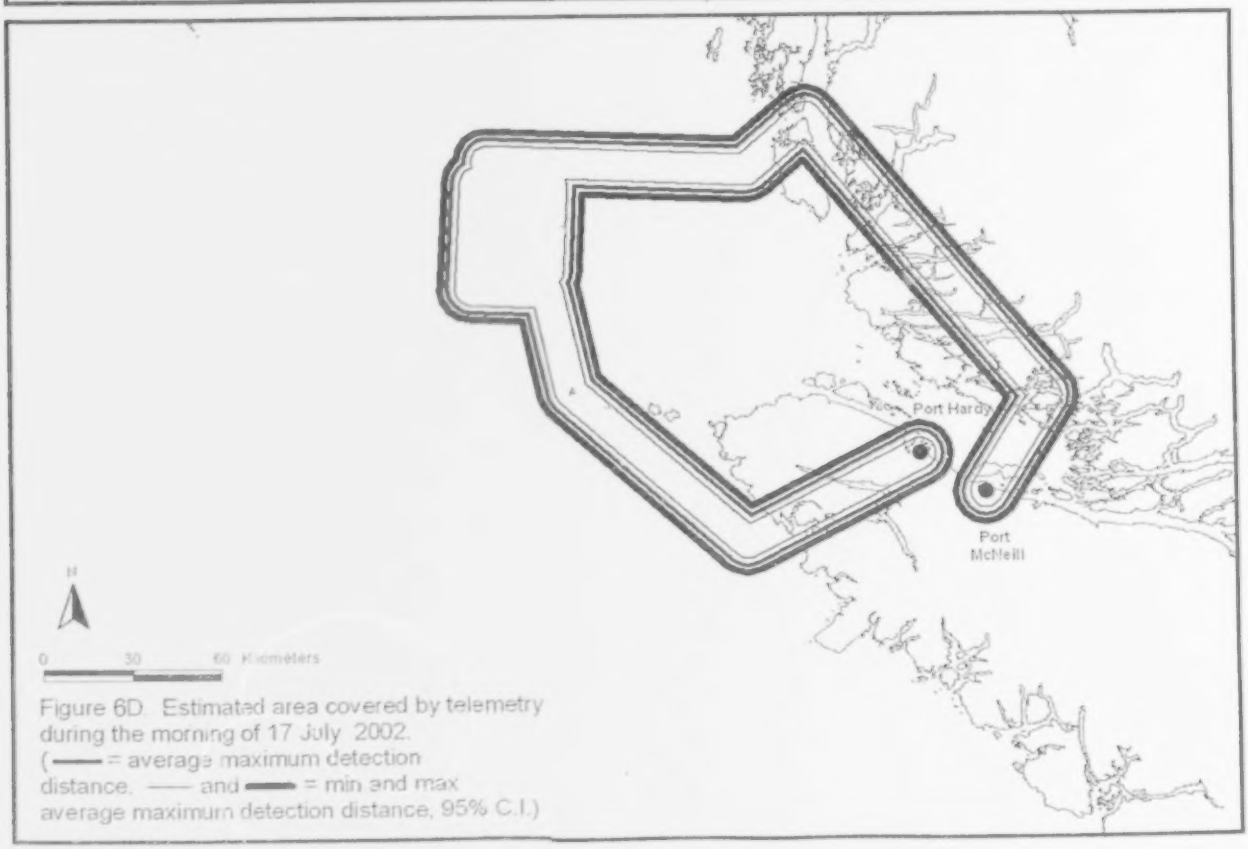

Figure 6D. Estimated area covered by telemetry during the morning of 17 July 2002. (—— = average maximum detection distance, —— and ▬ = min and max average maximum detection distance, 95% C.I.)

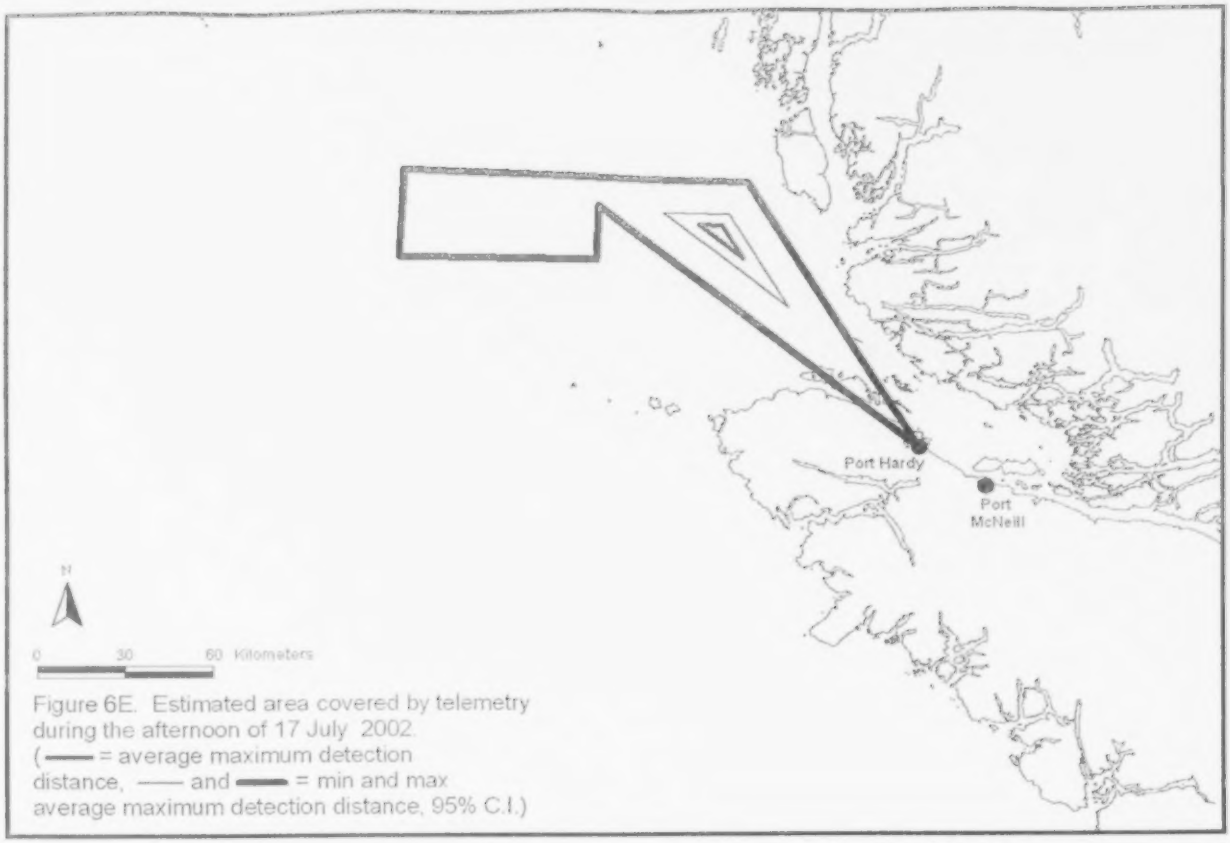

Figure 6E. Estimated area covered by telemetry during the afternoon of 17 July 2002.
(—— = average maximum detection distance, —— and —— = min and max average maximum detection distance, 95% C.I.)

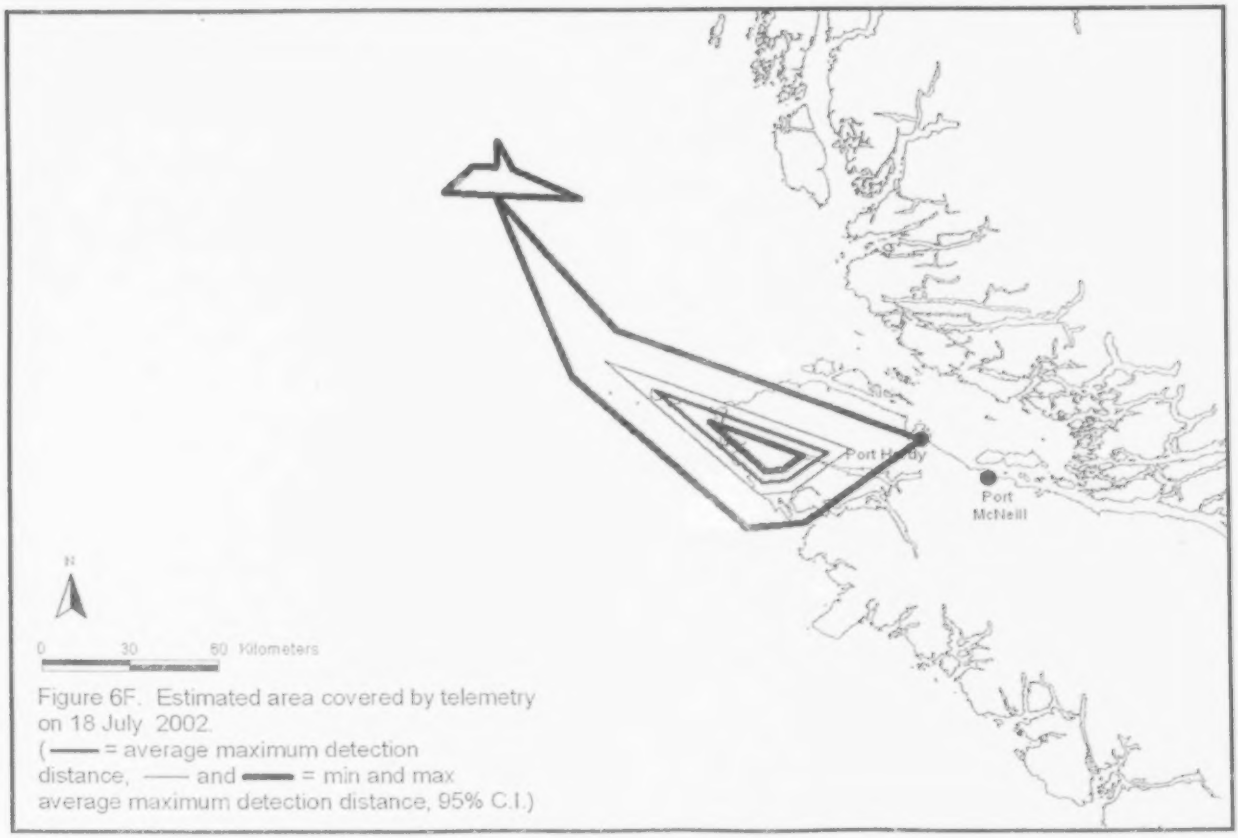

Figure 6F. Estimated area covered by telemetry on 18 July 2002.
(—— = average maximum detection distance, —— and —— = min and max average maximum detection distance, 95% C.I.)

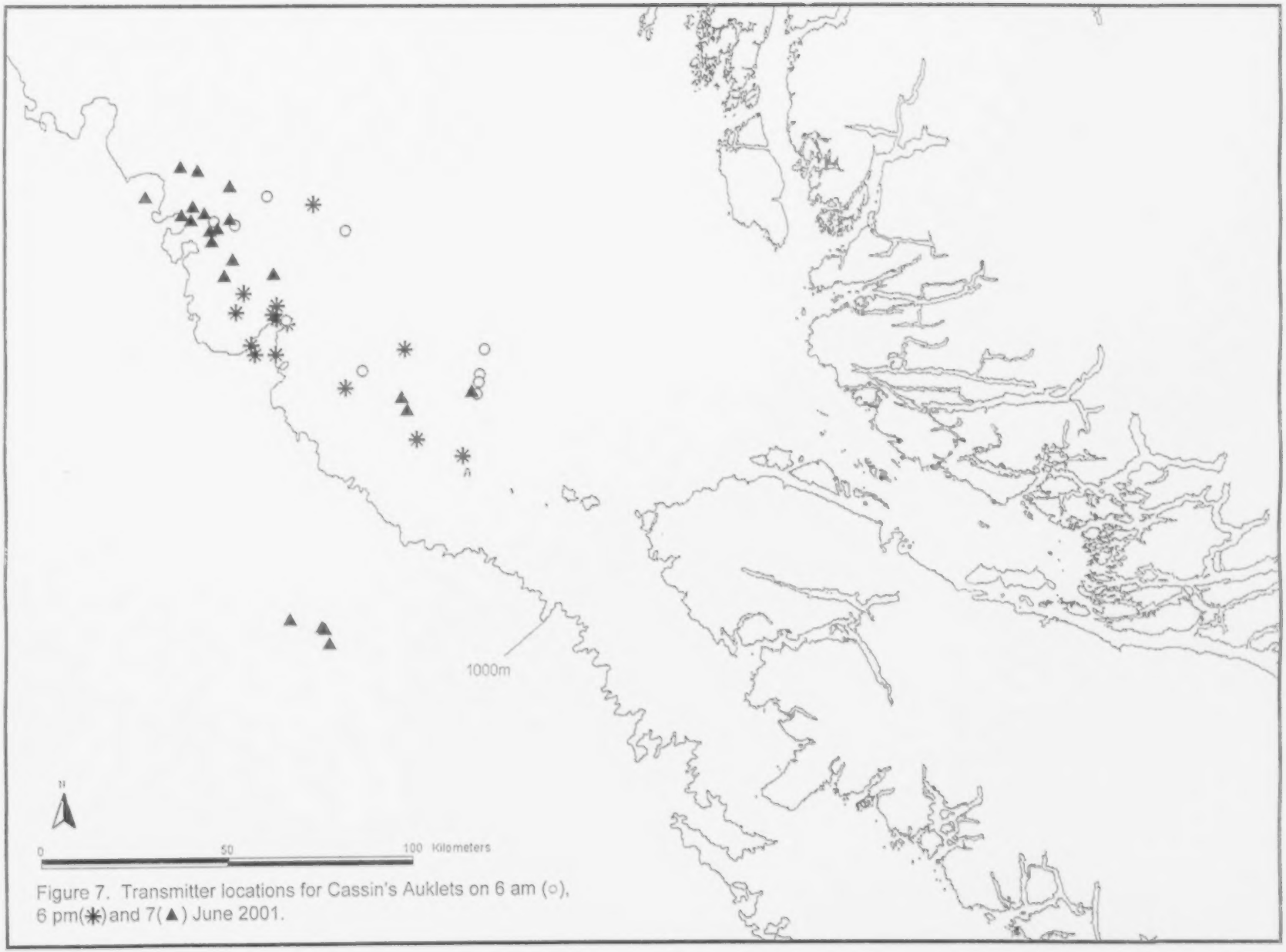

Figure 7. Transmitter locations for Cassin's Auklets on 6 am (○), 6 pm(✳)and 7(▲) June 2001.

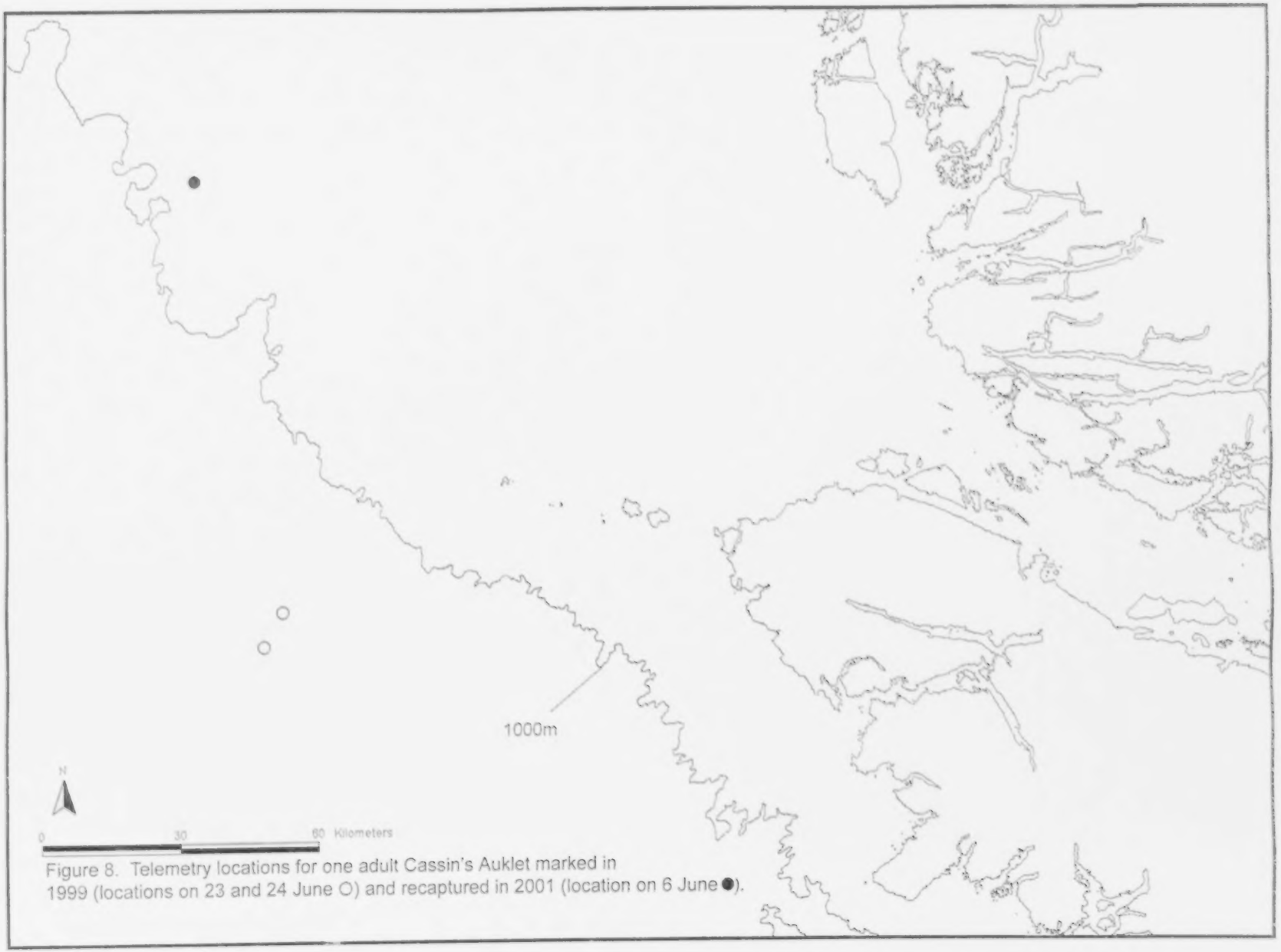

Figure 8. Telemetry locations for one adult Cassin's Auklet marked in 1999 (locations on 23 and 24 June ○) and recaptured in 2001 (location on 6 June ●).

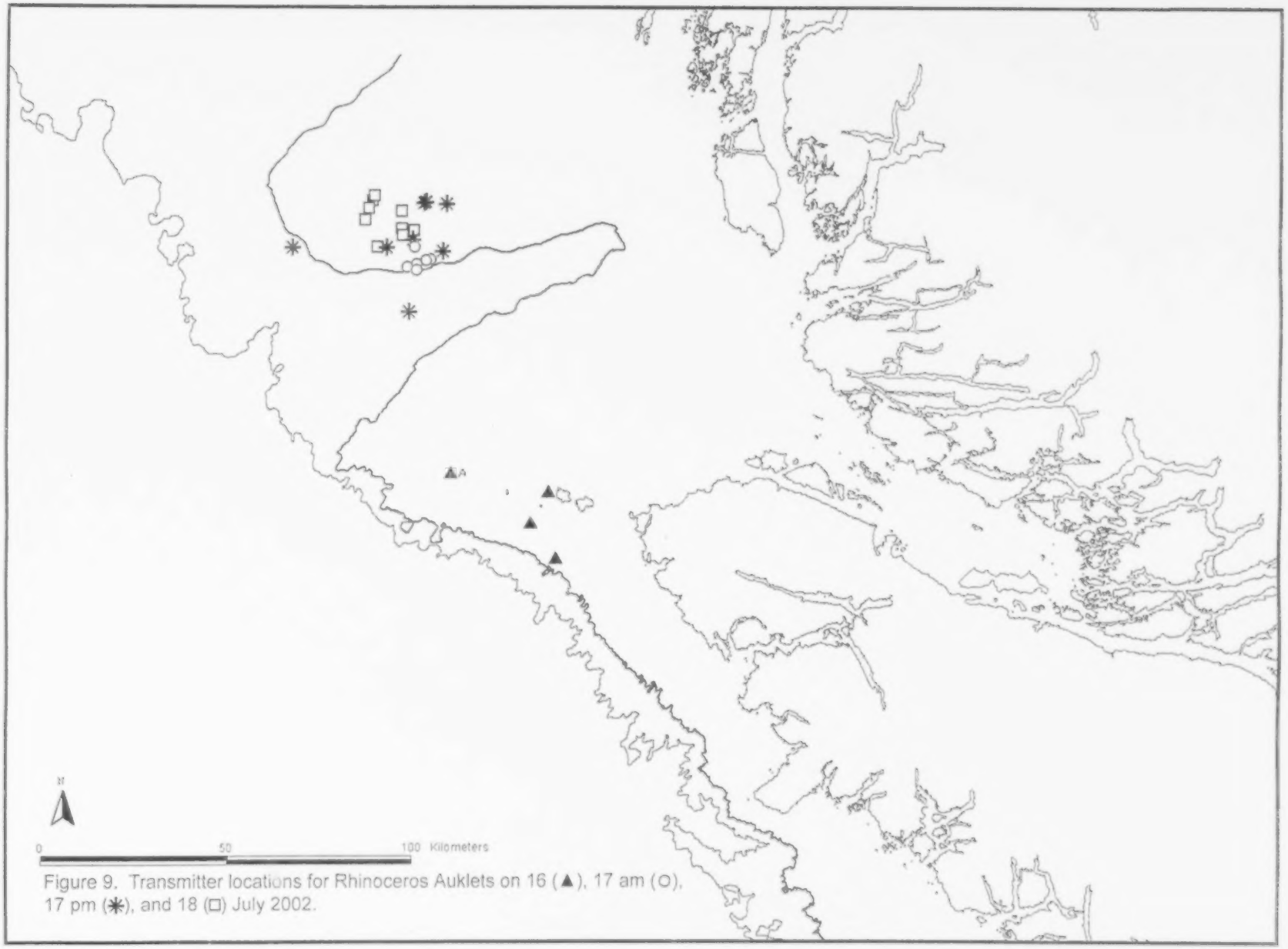

Figure 9. Transmitter locations for Rhinoceros Auklets on 16 (▲), 17 am (○), 17 pm (✱), and 18 (□) July 2002.

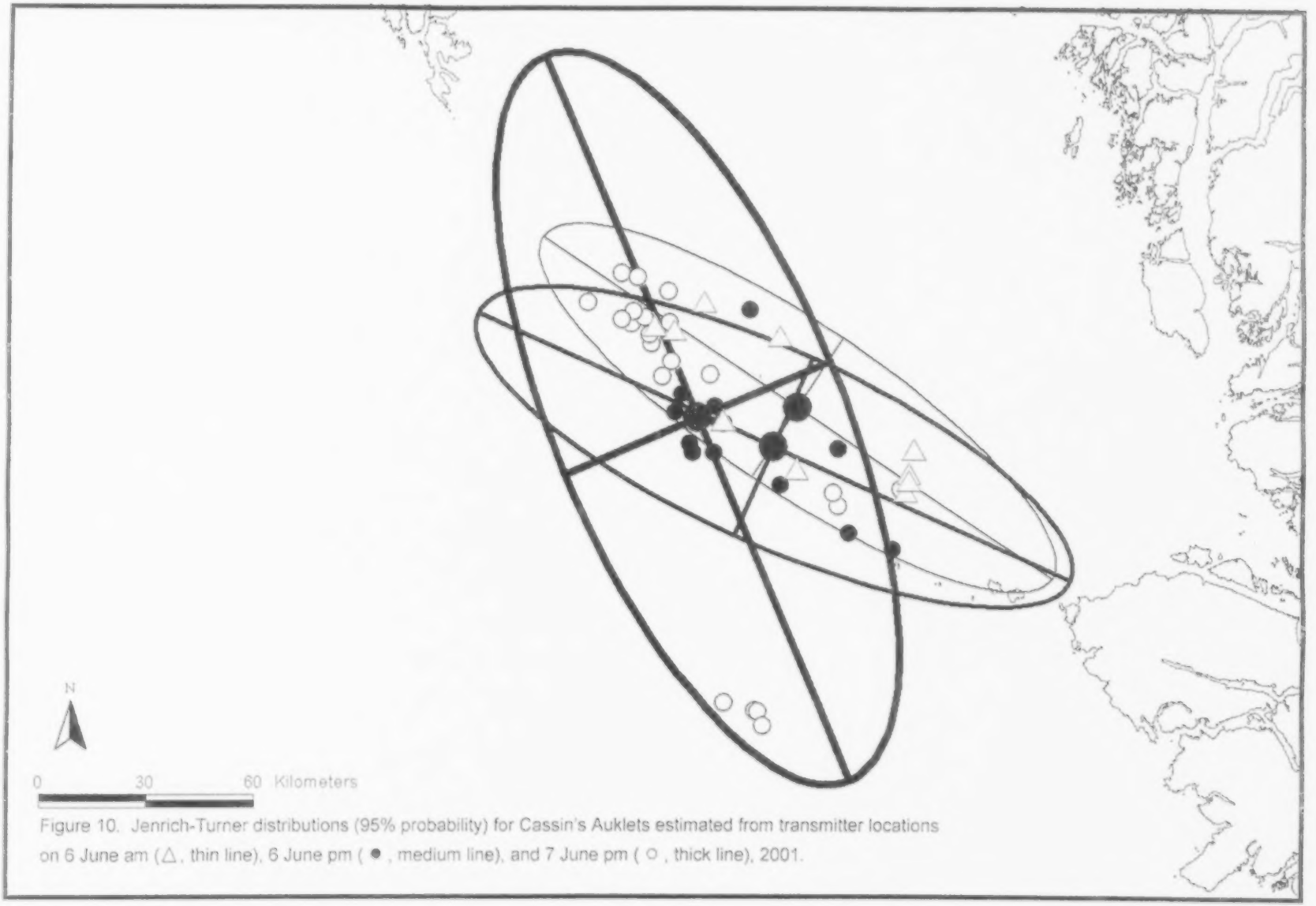

Figure 10. Jenrich-Turner distributions (95% probability) for Cassin's Auklets estimated from transmitter locations on 6 June am (△, thin line), 6 June pm (● , medium line), and 7 June pm (○ , thick line), 2001.

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